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VOLUME 22 NUMBER 8

AUGUST, 1932

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Official Organ of
The American Phytopathological Society

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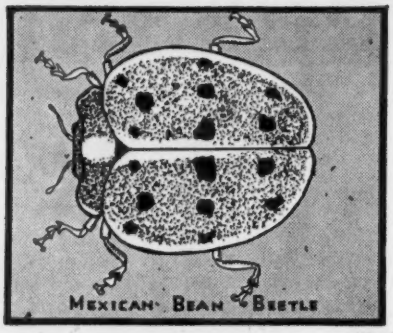

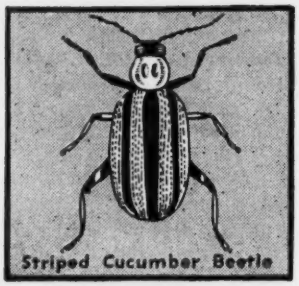

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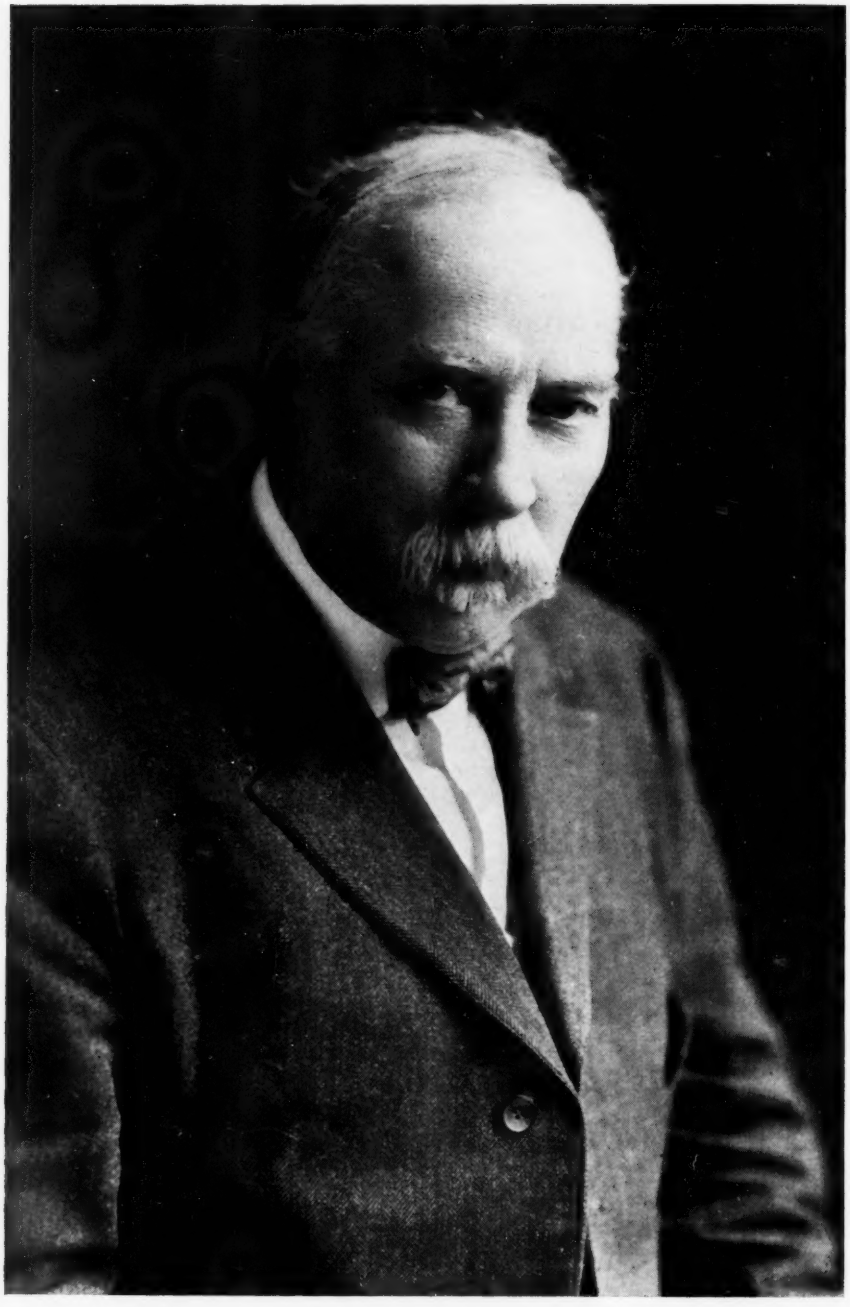

LOUIS HERMANN PAMMEL

PHYTOPATHOLOGY

VOLUME 22 NUMBER 8

AUGUST, 1932

LOUIS HERMANN PAMMEL
1862–1931

JOSEPH C. GILMAN

The death of Louis Hermann Pammel deprived The American Phytopathological Society of one of its charter members and its membership of a dear personal friend and associate. While primarily a taxonomist, he had capacity to devote himself to many other fields and to make notable contributions to the knowledge therein.

Dr. Pammel was born at La Crosse, Wisconsin, April 19, 1862, and, after being graduated from the University of Wisconsin in 1885, he continued his studies, first at Harvard University under Doctor Farlow and then at the Shaw School of Botany, Washington University, under Doctor William Trelease. In 1889 he received his master's degree from the University of Wisconsin. He returned to St. Louis in 1896 and received his doctor's degree from Washington University in 1899.

After leaving St. Louis in 1889, Doctor Pammel was called to Iowa State College to take charge of the botanical work left by Doctor Byron Halsted. At that time the staff of the botany department consisted of one person, himself. At the time of his death, March 23, 1931, the staff had grown to include 15 members, offering 56 courses, with major work in ecology, morphology, mycology, pathology, physiology, and systematic botany. Such expansion proclaims the man.

Doctor Pammel was a man of wide acquaintanceship, having contacts with persons in far places and many diverse callings. In all his endeavors the personal side of life had for him the greatest appeal. With his students and his associates he stressed the importance of the individual and his responsibilities to others, and he always found, on his many journeyings, a host of welcoming friends.

In his science Doctor Pammel was always a pioneer, and with that spirit he entered into all of his work. He was interested in the unknown and active in carrying through investigations in new fields. Thus, if the important contributions that he made be examined, it soon becomes apparent that he wanted to be on the frontiers of his chosen field. His early work was in plant pathology, and we find him in 1889 upholding a soil fungus as the causal agent of cotton root rot at a time when the dominant note in agriculture was emphasizing the importance of chemical balance in soils.

and explaining crop failures in terms of chemical deficiencies. Again, he was among the leaders in ascribing a plant disease to a bacterial organism in the case of the black rot of rutabaga when the question of bacterial diseases of plants was still controversial. Still later, he was among the first of his fellows to recognize the importance of some of the *fungi imperfecti* in cereal diseases, and his contributions on the Helminthosporium diseases of barley broke ground for many later studies on these fungi. In addition, Doctor Pammel made some of the earliest investigations on the use of fungicides to control the leaf spot of cherry, and he pointed out the futility of seed treatment for corn smut. These, with a continuous stream of short papers and observations on the occurrence of plant parasites, make up his contributions to pathology.

In our estimate of the man it must be remembered that plant pathology was not his main field of endeavor, for it was within the field of taxonomic botany that he felt most at home. In this sphere of influence he again showed his pioneering spirit. His encyclopedic "Poisonous Plants," his "Grasses of Iowa," and his "Weed Flora of Iowa," all were forerunners of a host of publications along very similar lines by other investigators. His last work, "Honey Plants of Iowa," brought together much data from a new point of view. One of the investigations in which he took most pleasure was his exploration of the vegetation of the Uintah Mountains, and, as he grew older, he got great enjoyment from visiting new places and comparing their floras with the one he knew so well, Iowa.

As a teacher the best criterion is doubtless the renown of the men who have sat at his feet. With Doctor Pammel such a test leaves little more to be said, for his students have reached the forefront of the ranks in all phases of botany and the enthusiasm for plants that he imparted has had a lasting influence.

Along with his teaching and his research Doctor Pammel always maintained an abiding interest in the social side of life. He was deeply religious and a leader in the work the churches were carrying on among the student bodies in our colleges. For years this work was a hobby, which he rode to a successful conclusion in the Episcopal Church at Ames as well as nationally. Another interest to which he gave much time was that of technical and honorary societies. He maintained membership in many foreign as well as American societies and served at different times as Secretary General to both Phi Kappa Phi and Gamma Sigma Delta. He was President General of the former, 1923–27. In 1919 he was Vice President of Section G of the American Association for the Advancement of Science.

Among the honors that Doctor Pammel received was the naming of a grass *Hordeum pammelii* Scribn. and Ball and of a smut *Entyloma pammelii* Hume in recognition of his work in grasses and their diseases.

Senecio pammelii Greenman was named for its discoverer. The degree of doctor of science was granted him by the University of Wisconsin in 1925.

In Iowa his most notable achievement was again in the pioneer field of conservation, and it was as the Chairman of the State Board of Conservation that he helped establish the system of State parks that has been a marked step in preserving many of the beauty spots of Iowa. Upon his retirement from the board a graceful tribute was paid to his work by naming the park area at Winterset after him.

When we look back over Doctor Pammel's life and his achievements we are reminded of the pioneers depicted by Joaquin Miller:

> "Full were they
> Of great endeavor. Brave and true
> As stern Crusader clad in steel,
> They died a-field as it was fit.
> Made strong with hope, they dared to do
> Achievement that a host today
> Would stagger at, stand back and reel,
> Defeated at the thought of it."

BIBLIOGRAPHY

(Compiled by C. M. King)

Mycology and Plant Pathology[1]

[1] Dr. Pammel's very extensive publications on numerous other lines are listed in the Proceedings of the Iowa Academy of Science 38: 1931.

Some mildews of Illinois. Jour. Mycol. **4**: 36–38. 1888.

Root rot of cotton, or "cotton blight." Texas Agr. Exp. Sta. Ann. Rpt. **1** (1888): 50–65. 1889.

Cotton root-rot. Texas Agr. Exp. Sta. Bul. 7. 1889.

Cotton root-rot. Texas Agr. Exp. Sta. Ann. Rpt. 2 (1889): 61–92. 1890.

A cherry disease. (Abst.) Iowa Acad. Sci. Proc. **1** (part I): 92–94. 1890.

Some fungous diseases of fruit trees in Iowa. (Abst.) Iowa Acad. Sci. Proc. **1** (part I): 91–92. 1890.

Fungus diseases of Iowa forage plants. I. Rusts. Mo. Rev. Iowa Weather and Crop Serv. **1** (5): 2–3. 1890.

Fungus diseases of Iowa forage plants. II. Smuts. Mo. Rev. Iowa Weather and Crop Serv. **1** (6): 1–4. 1890.

Fungus diseases of Iowa forage plants. III. Smuts of grasses. Mo. Rev. Iowa Weather and Crop Serv. **1** (7): 4–6. 1890.

Fungus diseases of Iowa forage plants. IV. Mildews. Mo. Rev. Iowa Weather and Crop Serv. 1 (12): 5–7. 1890.

Some fungus root diseases. Soc. Prom. Agr. Sci. Proc. **11** (1890): 91–94. 1890 (vol. 8).

Fungus diseases of Iowa forage plants. V. Ergot. Mo. Rev. Iowa Weather and Crop Serv. **2** (1): 2–5. 1891.

Fungus diseases of forage plants. VI. Spot diseases. Mo. Rev. Iowa Weather and Crop Serv. **2** (2): 8–9. 1891.

Fungus diseases of forage plants. VII. Bacterial diseases. Mo. Rev. Iowa Weather and Crop Serv. 2 (3): 8–11. 1891.

Fungus diseases of sugar beet. Iowa Agr. Exp. Sta. Bul. 15: 234–254. 1891.

Smuts wanted. Mo. Rev. Iowa Weather and Crop Serv. 2: April, 1891.

Treatment of fungus diseases. Iowa Agr. Exp. Sta. Bul. 13: 31–71. 1891.

Bacteria of milk, cream and cheese, with exhibitions of cultures. Iowa Acad. Sci. Proc. 1 (part II): 94. 1892.

Corn smut. Iowa Acad. Sci. Proc. 1 (part II): 95–96. 1892.

Experiments with fungicides. Iowa Agr. Exp. Sta. Bul. 16: 315–329. 1892.

Fungus diseases and weather. Mo. Rev. Iowa Weather and Crop Serv. 3 (10): 8–10. 1892.

Some fungus diseases of Iowa forage plants. (Abst.) Iowa Acad. Sci. Proc. 1 (part II): 93–94. 1892.

Some diseases of plants common to Iowa cereals. Iowa Agr. Exp. Sta. Bul. 18: 488–505. 1892.

Treatment of some fungus diseases. Iowa Agr. Exp. Sta. Bul. 17: 418–443. 1892.

An aromatic bacillus of cheese (*Bacillus aromaticus* n. sp.). Iowa Agr. Exp. Sta. Bul. 21: 792–796. 1893.

Bacteria, their relation to modern medicine, the arts and industries. President's retiring address. Iowa Acad. Sci. Proc. 1 (part IV): 66–91. 1894.

Diseases of the cherry. Iowa State Hort. Soc. Rpt. 28 (1893): 248–253. 1894.

Diseases of foliage and fruit. Iowa State Hort. Soc. Rpt. 28 (1893): 467–474. 1894.

Experiments in the treatment of spot disease of the cherry, diseases of currants and potato blight. Iowa Agr. Exp. Sta. Bul. 20: 716–720. 1893.

Machinery and methods for spraying. Iowa Agr. Exp. Sta. Bul. 20: 706–712. 1893. (With H. Osborn.)

The most important factor in the development of rust. Soc. Prom. Agr. Sci. 15 (1893): 287–291. 1894 (vol. 11).

Notes on a few common fungus diseases. Iowa Agr. Exp. Sta. Bul. 23: 918–924. 1893.

Prevention of corn [and] oats smut. Iowa Agr. Exp. Sta. Bul. 20: 721–728. 1893. (With F. C. Stewart.)

Sclerotinia libertiana Fuckel, with a bibliography of fungus root diseases. Trans. St. Louis Acad. Sci. 6: 193–232. 1893.

Experiments in treating oats with different chemicals and hot water. Iowa Agr. Exp. Sta. Bul. 24: 988–990. 1894. (With F. C. Stewart.)

Further notes on *Cladosporium carpophilum* von Thümen. (Abst.) Iowa Acad. Sci. Proc. 1 (part IV): 92–93. 1894.

Powdery mildew of the apple. (Abst.) Iowa Acad. Sci. Proc. 1 (part IV): 92. 1894.

Résumés and Abstracts. Recent bacteriological work. Agr. Sci. 8: 114–119. 1894.

Bacteriosis of rutabaga (*Bacillus campestris* n. sp.). Iowa Agr. Exp. Sta. Bul. 27: 130–134. 1895.

Bacteriosis of rutabaga (*Bacillus campestris* n. sp.). Amer. Mo. Micros. Jour. 16: 145–151. 1895.

Diseases of plants at Ames, 1894. Iowa Acad. Sci. Proc. 2 (1894): 201–208. 1895.

Treatment of currants and cherries to prevent spot diseases. Iowa Agr. Exp. Sta. Bul. 30: 289–301. 1895. (With G. W. Carver.)

Fungus diseases of plants. Mo. Rev. Iowa Weather and Crop Serv. 7 (1): 4–5; (2): 9–10; (4): 5–7; (7): 8–9. 1896.

Fungus diseases of plants at Ames, Iowa, 1895. Iowa Acad. Sci. Proc. 3 (1895): 140–148. 1896. (With George W. Carver.)

Some notes on chromogenic bacteria. Iowa Acad. Sci. Proc. 3 (1895): 135–140. 1896. (With R. Combs.)

A contribution on the gases produced by certain bacteria. Centralbl. Bakt. [etc.] Abt. II. 2: 633–650. 1896. (With Emma Pammel.)

Bacteriological study of the Marshalltown water supply. Abst. of the results of L. H. Pammel. Iowa Geol. Surv. Ann. Rpt. 7 (1896): 260–262. 1897.

Notes on dairy bacteriology. Iowa Agr. Exp. Sta. Bul. 34: 687–691. 1897. (With I. J. Mead.)

The course in cryptogamic botany. Soc. Prom. Agr. Sci. Proc. 21: 169–172. 1900.

Powdery mildew of the apple. Iowa Acad. Sci. Proc. 7 (1899): 177–182. 1900.

The asparagus rust in Iowa. Iowa Agr. Exp. Sta. Bul. 53: 60–67. 1900. (With E. R. Hodson.)

Notes on the bacteriological analysis of water. Iowa Acad. Sci. Proc. 8: 262–275. 1901.

Miscellaneous notes on fungus diseases. Iowa Agr. Exp. Sta. Bul. 61: 139–142. 1902.

Public water and ice supplies and disposal of sewage. Iowa Engineering Soc. Proc. 15: 32–52. 1903.

Public water and ice supplies and disposal of sewage. State Board of Health of Iowa Rpt. for period ending June, 1903: 141–164. 1903.

Fungus diseases of plants and their remedies. Iowa State Hort Soc. Rpt. 38 (1903): 440–444. 1904.

Some unusual fungus diseases in Iowa during the summer of 1903. Soc. Prom. Agr. Sci. Proc. 25: 144–156. 1904.

Some bacteriological examinations of Iowa waters. Iowa Acad. of Sci. Proc. 11 (1903): 111–126. 1904. (With R. E. Buchanan and Edna L. King.)

An investigation of some Iowa sewage disposal systems. Centralbl. Bakt. [etc.] Abt. II, 13: 395–407. 1904. (With J. B. Weems.)

Some of the more important fungus diseases of 1904. Iowa State Hort. Soc. Rpt. 39 (1904): 244–249. 1905.

Cedar apple fungi and apple rust in Iowa. Iowa Agr. Exp. Sta. Bul. 84: 3–36. 1905.

Some fungus diseases common in Iowa during the season of 1904. Soc. Prom. Agr. Sci. 26: 69–82. 1905.

Some railroad water supplies. Iowa Acad. Sci. Proc. 12 (1904): 151–155. 1905. (With Estelle D. Fogel.)

Some mycological contributions during the year 1905. Iowa State Hort. Soc. Rpt. 40 (1905): 218–230. 1906.

Some diseases of Rocky Mountain plants. Iowa Acad. Sci. Proc. 13: 89–114. 1906.

Some phytopathological problems. Soc. Prom. Agr. Sci. 27: 76–88. 1906.

Some municipal water problems. Iowa Acad. Sci. Proc. 14: 115–146. 1907.

Discussion of fungous diseases. Iowa State Hort. Soc. Rpt. 43 (1908): 39–40. 1909.

Fungus diseases during the season 1908. Iowa State Hort. Soc. Rpt. 43 (1908): 265–270. 1909.

Some plant diseases of 1908. Iowa Agr. Exp. Sta. Bul. 104. 1909. (With Charlotte M. King.)

Notes on factors in fungous diseases of plants, with records of occurrences of plant diseases at Ames for a period of twenty-five years. Iowa Acad. Sci. Proc. 16: 41–97. 1909. (With Charlotte M. King.)

Two barley blights. Iowa Agr. Exp. Sta. Bul. 116. 1910. (With Charlotte M. King and A. L. Bakke.)
Legislation of fungous diseases of plants. Iowa State Hort. Soc. Rpt. 45 (1910): 192–194. 1911.
Notes on the fungous diseases of plants. Iowa State Hort. Soc. Rpt. 45 (1910): 225–233. 1911.
Some fungus diseases of trees. Iowa Acad. Sci. Proc. 18: 25–33. 1911.
Fungous diseases of Iowa for the year 1911. Iowa State Hort. Soc. Rpt. 46 (1911): 172–179. 1912.
Four new fungous diseases in Iowa. Iowa Agr. Exp. Sta. Bul. 131. 1912. (With Charlotte M. King.)
Diseases of plants in Iowa for 1912. Iowa State Hort. Soc. Rpt. 47 (1912): 199–213. 1913.
Cornstalk and corn root diseases in Iowa. Iowa Agr. Exp. Sta. Circ. 21. 1915. (With Charlotte M. King and J. L. Seal.)
Fungus diseases of plants for 1916. Iowa Yearbook of Agr. 17: 574–582. 1916.
Ergot in rye. Amer. Jour. Vet. Med. 13: 398. 1918.
Perennial mycelium of parasitic fungi. Iowa Acad. Sci. Proc. 25: 259–263. 1918.
The extermination of the common barberry to prevent crop leakage due to stem rust. Iowa State Hort. Soc. Rpt. 53 (1918): 401–406. 1919.
The relation of native grasses to *Puccinia graminis* in the region of Iowa, western Illinois, Wisconsin, southern Minnesota and eastern South Dakota. Iowa Acad. Sci. Proc. 26: 163–192. [1919.]
The teaching of plant pathology. Iowa Acad. Sci. Proc. 28: 263–264. 1921.
Clover mildew a serious menace. Vet. Med. 17: 648–649. 1922.
The powdery mildew of clover. Vet. Med. 17: 780. 1922.
The species of Rhamnus in southwestern United States and the Pacific Coast and *Puccinia coronata*. Iowa Acad. Sci. Proc. 29: 267–270. 1922.
Ergotism. Vet. Med. 18: 632–633. 1923.
Is corn smut poisonous? Vet. Med. 18: 950. 1923.
Mucor corymbifer affects eyes of horses. Vet. Med. 19: 646. 1924.
Is corn smut poisonous? Vet. Med. 20: 506. 1925.
Moldy corn. Vet. Med. 20: 200–201. 1925.
Moldy oat hay. Vet. Med. 20: 154. 1925.
Injurious molds on sweet corn. Vet. Med. 21: 70. 1926.
A new species of Hygrophorus. Iowa State Col. Jour. Sci. 2: 115. 1927.
Probably a cryptogam poisoning due to mold on corn. Vet. Med. 23: 29. 1928.
Smuts not poisonous. Vet. Med. 24: 256. 1929.
Ergotism of small grain. Vet. Med. 25: 92. 1930.

THE EFFECT OF THE SUGARY GENE IN CORN ON RESISTANCE TO SEEDLING BLIGHT CAUSED BY GIBBERELLA SAUBINETII[1]

P. H. SENN[2]

INTRODUCTION

It has been recognized during recent years that the organism *Gibberella saubinetii* (Mont.) Sacc. is largely contributory to seedling blight of corn in the United States. During the year 1927 the loss caused by this organism was estimated[3] at 1.6 per cent of the entire crop or approximately 50,000,000 bu. of corn.

Several investigators (10, 14) report that both dent and sweet corn have many diseases in common but in nearly all instances the effects are more severe on sweet corn. These reports seem to agree with general observations made in Wisconsin, and studies were begun at the University of Wisconsin in 1927 in an attempt to determine more definitely the relative resistance of sweet corn to the seedling-blight organism, *Gibberella saubinetii*, compared to the resistance of nonsweet or starchy corn.

In the present investigation it was desired to determine whether sweet corn as a class, just because it is sweet corn rather than field corn, is more susceptible to seedling blight or whether the apparent difference in resistance of the two classes of varieties is due to some other factor or factors.

MATERIALS AND METHODS

Foundation stocks. The foundation material for this study was obtained from stocks of inbred and crossbred ears produced at the Wisconsin Agricultural Experiment Station at Madison. The inbred lines were represented by dent, flint, and sweet corns of locally adapted varieties. The crossbred ears were produced by crossing the sweet corns with the flint and dent varieties.

[1] Paper from the Department of Genetics, University of Wisconsin, No. 130. Published with the approval of the Director of the Station.

[2] Assistant Professor of Farm Crops and Genetics, University of Florida, Gainesville. The writer acknowledges his indebtedness to Dr. R. A. Brink, Professor B. D. Leith, and Dr. J. G. Dickson, all of the University of Wisconsin, for general guidance and helpful advice throughout the period of the investigation and in the preparation of the manuscript.

[3] Plant Disease Survey. Crop losses from plant diseases in the United States in 1927. U. S. Dept. Agr., Bur. Plant Indus., Plant Disease Rptr. Sup. 64: 379. 1928. (Mimeographed).

In 1901 Correns (2) found a single genetic factor difference between the starchy and the sweet endosperm characters. The sugary character is recessive in inheritance to the nonsugary or starchy condition.

Ears segregating for the sugary and the nonsugary kernels were needed for testing against the seedling-blight organism. To obtain these some heterozygous plants were self-pollinated, while others were back crossed to sugary plants. Both procedures resulted, of course, in ears segregating for sugary and nonsugary kernels. Segregating ears were produced also by crossing reciprocally sugary and heterozygous nonsugary plants. This resulted in kernels of the classes of similar residual genetic constitution but produced upon the 2 respective types of plants, sugary and nonsugary. These ears were used in studying the effects of the constitution of the mother plant.

The ears were produced during the summers of 1927 and 1928 at the Wisconsin Agricultural Experiment Station at Madison, Wisconsin. As the ears were harvested in the fall they were dried on hangers in a steam-heated room equipped with electric fans for circulating the air.

The organism. The seedling blight dealt with in this manuscript is caused by a fungus, the conidial stage of which is known as *Fusarium graminearum* Schwabe, its ascigerous form being known as *Gibberella saubinetii.* Throughout the study, a single physiologic form of the organism was used. The organism was obtained from the Department of Plant Pathology of the University of Wisconsin under Wisconsin No. 259. Inoculations were made with 5- to 7-day-old cultures grown on potato-dextrose agar at room temperature.

Dickson (3), in his work with Gibberella, has pointed out that the rate of growth of the mycelium and the production of conidia, extend over a wide range of temperatures, from 4° to 34° C., but the most vigorous development is around 24° to 29°. Corn, however, makes its most vigorous growth at soil temperatures around 24° to 28° C. The most favorable soil temperature for the blighting of corn ranges from 8° to 20° C. Above 24° C. no blighting occurs.

Greenhouse technique. Experimental conditions modify considerably the expression of the disease symptoms. Consequently, reduction of variability in environment becomes essential if reliable comparisons are to be made. Temperature is one of the main variables. Absolute control of temperature in the greenhouse is, of course, impossible. The disease-resistance studies, however, were made in the greenhouse during the winter months when the temperature outside was low. The greenhouse temperature was automatically regulated by thermostats and a motor-driven blower so adjusted that when the greenhouse temperature exceeded a certain degree, cool air was drawn in from outside.

McIndoe (15) points out that not only should the temperature be constant throughout the experimental period but an equal distribution of heat over the greenhouse should be assured. This is especially necessary if a dependable estimation of relative resistance is desired. In addition to the blower, an electric fan was installed in the greenhouse at a point advantageous for circulating the air freely.

Soil temperatures were recorded 3 times daily, morning, noon, and evening, from thermometers placed about 1.5 in. deep in the soil. The temperature showed small variations, being highest at midday, as was to be expected. There were slight daily variations but these were within the range for the expression of seedling blight.

The inoculation test. Due to the limited number of the 2 kinds of kernels, 40 sugary and 40 nonsugary seeds from each segregating ear were usually planted in the inoculation test. Ten additional kernels of each kind were planted on the same kind of soil but uninoculated. The noninoculated sample adjoined the inoculated one with only a division board separating them. Ten other kernels from the same lots of seed were placed on a germinator bench for a study of germination percentage and relative vigor of seedlings and for observations as to the presence of seed-borne organisms. The same procedure was followed with both the nonsugary and the sugary kernels of the same ear. Just before planting, the kernels to be tested were placed in an aqueous conidial suspension of the Gibberella organism for about 10 minutes. The concentration of the suspension was usually around 750,000 conidia per cc.

The sugary and nonsugary kernels from the same ear, when being tested for relative resistance, were always planted side by side in rows 3 in. apart in the bench. Such an arrangement placed the two lots of kernels under as nearly identical conditions as it seemed possible to provide. The planting arrangement is shown in figure 1. The soil used was a half-and-half mixture of well-rotted sod and sand. After being sifted through a $\frac{3}{8}$-in.-mesh screen, the soil was friable and in condition for removing the seedlings and for washing the roots preparatory to reading the results of the test.

The moisture content of the soil was maintained at what seemed to be the most favorable percentage for the germination and growth of the young plants.

Germination tests. Ten sugary and 10 nonsugary kernels from each segregating ear were placed on the germinator in rows side by side. Besides the germination percentage on each lot, the vigor of the seedlings was observed. Observations on the number of healthy seedlings as well as on the presence of various kinds of seed-borne organisms were likewise recorded.

The germinator used was of the limestone-sawdust type described by Hoffer and Holbert (8). The kernels were placed between sterilized cloths and kept moist by daily sprinklings. The germinator was located in a basement where the temperature differed little from that maintained in the greenhouse where the inoculation tests were run. Records were taken on the seedlings after about 14 days on the germinator.

From the noninoculated or control bench, records were obtained on the percentage of kernels germinating, the number of healthy plants, and the number having lesions or blighting. As nearly as possible without plating, the cause of the lesions or the blighting was determined. The combined records from the control bench and the germinator served as the basis for analyzing the results of the inoculation trials.

FIG. 1. As shown in the planting arrangement above, sugary and nonsugary kernels from each ear are planted side by side in rows 3 in. apart in the inoculated bench. The corresponding noninoculated or control seedlings may be seen beyond the division board. A high correlation between the reaction to the fungus of the sugary and nonsugary seedlings from a given ear is in evidence. In the middle foreground the sugary and nonsugary seedlings from 3 resistant ears are seen. At the right and left of this group both classes of seedlings are highly susceptible. It is evident that genes other than the Su-su pair may play an important rôle in determining resistance and susceptibility.

Symptoms of seedling blight. As Dickson (3) has pointed out, the symptoms of corn-seedling blight caused by Gibberella are variable, depending upon many factors, such as severity of attack, the age of the seedling, and the environmental conditions during the development of the disease. The seedling may be attacked at various stages. The regions of attack are primarily the coleorhiza and the cortex of the mesocotyl. In the case of severe attacks many of the seedlings may be killed before they reach the surface of the soil. In most cases the developing embryo is invaded and killed before either plumule or roots elongate. Some seedlings do not succumb to the attack until the 1st- or 2nd-leaf stage. The parasite invades

the cortical tissues of the young seedlings, causing them to become dwarfed and chlorotic.

Rather definite lesions usually extend from the kernel into the seminal root and adventitious roots as well as into the mesocotyl. The fungus invades the outer soft or parenchymatous tissue, which usually becomes light brown to reddish brown and water soaked in appearance. While the badly infected seedlings become yellow and wilt, many of the plants partially recover by sending out roots usually at the node above the lesion and make a fair growth.

Classification of the seedlings. Since the symptoms of seedling blight are most pronounced in the early stages of the life of the corn plant, the seedlings were grown to the 3rd- or 4th-leaf stage, in a period of about 21 days. On completion of the test the seedlings were classified into 5 groups, according to a scheme devised by Hoppe (unpublished) as follows: (1) Healthy, (2) restricted lesions, (3) endodermal resistant, (4) blighted after emergence, (5) blighted before emergence.

The "healthy" class included those plants showing no lesions.

The "restricted-lesions" class comprised the plants showing one or more small lesions either in the region where the primary root comes out of the coleorhiza or in any restricted area of the mesocotyl.

In cases where the lesion had completely encircled the mesocotyl and at the same time the seedling was showing signs of sending out secondary roots above the lesion the plants were placed in the "endodermal-resistant" class. Here resistance is exhibited through the activities of the endodermis and pericycle, preventing the fungus from entering the stele until after the seedling has had time to send out secondary roots at the node above the lesion. The young plant is thus enabled to obtain water and nutrients through these secondary roots and will often grow to maturity.

In the "blighted-after-emergence" class are placed those plants that have gotten aboveground and have begun photosynthesis but are so badly diseased that they blight.

The "blighted-before-emergence" class includes those individuals in which the pericarp bursts and the embryo begins to grow but in which the young plant is unable to push its way above the soil.

The 5 classes are represented in figure 2. While it is recognized that the classes are only relative groupings, they represent, however, an attempt at measuring the degree of resistance shown by the seedlings.

In making a comparative study involving 2 groups of material differentiated by one pair of genetic factors, such as nonsugary and sugary, it is important to reduce the effects of other factors to a minimum. The two groups of material should be made as nearly comparable as possible

with the exception of the one essential pair of genes differentiating the two groups.

In order to make other environmental as well as genetic factors comparable in the two lots of seed, the pollinations were so controlled that the two types of kernels were produced on the same cob. With the two types of kernels scattered at random over the entire ear, it seemed reasonable to suppose that the differences of environment were minimized as far as is possible under the circumstances. Moreover, with this procedure the effects of the residual inheritance on resistance should be the same for both classes of seedlings.

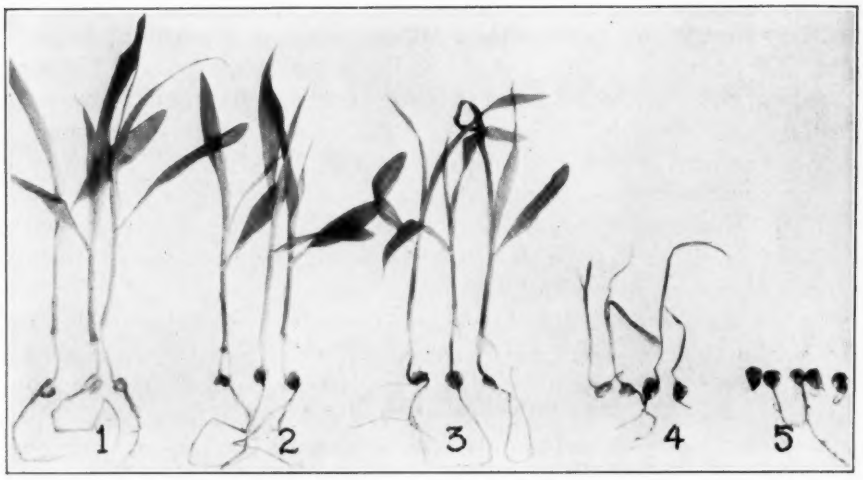

FIG. 2. Representative seedlings in the 5 classification groups: 1, Healthy; 2, restricted-lesions; 3, endodermal-resistant; 4, blighted-after-emergence; 5, blighted-before-emergence.

Index of resistance. In arriving at a figure that would represent the relative degree of resistance of a given lot of seedlings, a method was used that involves the assignment of a numerical value to each of the 5 classes, as follows:

Class	*Resistance value*
Healthy	8
Restricted-lesions	6
Endodermal-resistant	4
Blighted-after-emergence	2
Blighted-before-emergence	0

In arriving at the net resistance for a particular group of seedlings, the number of seedlings in each class was multiplied by the resistance value

for that particular class. The sum of the products was then divided by the total number of seeds germinating. The result was taken as the average resistance of the group and is termed the "resistance index." However, this method ignores the kernels that do not form a sprout. Some kernels exhibit no growth beyond a slight break in the seed coat. This break opens an avenue of entrance for the organism. The seedling might be attacked before hardly any growth of it would be in evidence. Such seedlings would be classified as "dead" or as "not germinating," when rightfully they belong in the blighted-before-emergence class.

Some kernels were questionable as to classification. In order to give consideration to this point it was thought best to reckon the vitality of a group of kernels under inoculation by the percentage of kernels germinating on the germinator and on the control bench. When the total resistance of a group was divided by the calculated vitality of the group, the average resistance for the group of kernels tested was obtained. This method was employed in arriving at the resistance indices for the various groups of kernels tested.

For determining whether a significant difference in resistance to seedling blight was shown between the groups of sugary and the nonsugary kernels, Fisher's (7) method for arriving at the significance of a mean was employed. The resistance index of one group of kernels was paired with the resistance index of the other group of the same ear.

STATISTICAL COMPARISONS

On lot of 126 ears segregating for the two kernel characters was subjected to test. Here no consideration was given to the possible presence of any kind of seed-borne organism. In this lot it was found that the nonsugary kernels showed a greater degree of resistance to Gibberella than the sugary kernels, by an amount equal to 0.92 in terms of the resistance index. When this difference is evaluated in Fisher's tables of probability (tables of t) it is found to be statistically significant.

Seed-borne organisms. One of the outstanding things noted when reading the results on the germinator was the prevalence of seed-borne organisms on the kernels. However, such a condition does not seems to be unusual, particularly in certain seasons. Holbert and his coworkers (11) tested in 1920–21 more than 2,000 bushels of seed corn before they obtained a desired sample of 75 ears that was 100 per cent viable and nearly disease free. Moore (17) of the New Jersey station was unable to find a single sample that was entirely free from organisms.

Various pathogenic organisms were found on the kernels when reading the germinator, chief among which were Penicillium, Basisporium, and Rhizopus. Records were made of the kernel lots carrying these seed-borne

organisms. The particular kind of organism present on them was noted also in so far as could be determined without plating out the individual kernels.

Preference of organisms. A study was made to see if a particular organism showed a preference on the ear for either the sugary or the nonsugary type of kernel. Twenty ears segregating in a 1:1 ratio were available for this study. These ears were used because the nonsugary and sugary kernels on each ear were approximately equal in number.

Samples of about 50 seeds each of the sugary and the nonsugary types were taken from each ear. In taking samples all the kernels from a particular area on the cob running from butt to tip were included. The ear was divided roughly into 3 sections, butt, middle, and tip. The kernels from each section were placed in a separate group on the germinator, and the nonsugary kernels were separated, of course, from the sugary.

The percentage of infection was recorded on each type of kernel in each section, and the different types of organisms observed on each of the infected kernels were also recorded. Penicillium and Rhizopus were the two most prevalent organisms. No apparent preference was shown by either of these organisms for the sugary or the nonsugary kernels.

Among the more than 2,000 kernels tested on the germinator from the 20 ears, there were only 4 kernels exhibiting an infection of Gibberella. Three of these infected kernels were nonsugary and one was sugary. Basisporium was found on 5 of the 20 ears. In every case except one the nonsugary kernels showed a slightly higher infection than did the sugary kernels. However, in only one case was the number of Basisporium-infected kernels as great as 9 on any single ear, and in this case there were 5 nonsugary and 4 sugary kernels infected with the organism.

Such results indicate that the more prevalent organisms seem to have very little, if any, preference for the one type of kernel over the other. The test also shows that the seed-borne organisms do not appear to be confined to any particular area but are scattered along the ear from butt to tip, as shown by the rather general distribution among the different sections of the ear.

Seed-borne organisms and resistance. It was not known what pathological influence upon the host any one of the seed-borne organisms might have in the presence of another fungus. Realizing this fact, it seemed necessary to determine the various organisms upon the ears and to analyze the data obtained from the kernels inoculated with Gibberella accordingly. It was desired to know if the presence of any of these organisms materially affected the relative resistance of the sugary and the nonsugary kernels to Gibberella. The basis of the ear grouping rests upon the presence or absence on the kernels of any one of the above-named seed-borne organisms. For a sta-

tistical study the ears were grouped with reference to the seed-borne organisms, as shown in table 1.

Difference in resistance. In a group consisting of 84 ears Gibberella was not observed on either the sugary or the nonsugary kernels. When inoculated with Gibberella the nonsugary seedlings exhibited a resistance index greater by 0.98 of a unit than that of the sugary seedlings. This higher resistance of the nonsugary kernels is statistically significant. Another group consisted of ears where Gibberella was observed on a few of the nonsugary kernels but not on the sugary. In this group the resistance index of the nonsugary class exceeded that of the sugary by 0.98 of a unit. There were 18 ears whose record on the germinator showed no evidence of Gibberella on the nonsugary seeds, but the organism was observed on some of the sugary kernels. Here, again, the greater resistance to Gibberella is shown by the nonsugary seedlings, the difference being 0.79 of a unit. In a 4th lot of ears involving Gibberella, where the organism was present on both the nonsugary and sugary kernels, a mean difference in resistance to Gibberella infection of 0.40 unit was found. Again, the greater resistance was in favor of the nonsugary kernels.

Another grouping was made on the basis of the presence or absence on the germinator of Penicillium. In a lot of 21 ears in which Penicillium was not observed on the germinator on either the sugary or the non-sugary kernels, the resistance of the nonsugary kernels exceeded that of the sugary by 0.68 of a unit. Another lot, composed of 19 ears, showed Penicillium on the nonsugary but not on the sugary kernels on the germinator. When the kernels were inoculated with Gibberella, the nonsugary seedlings gave the higher resistance index, the difference being 0.74 of a unit. A group of 24 ears was studied that showed no Penicillium on the nonsugary, but the organism was found to be present on some of the sugary kernels. The resistance index of the nonsugary seedlings was higher by 1.4 units than that of the sugary seedlings. Penicillium was observed on the germinator on both the nonsugary and the sugary kernels of 60 segregating ears. In this case a difference in the resistance indices of 0.88 was found, again in favor of the nonsugary seedlings.

One set of ear groupings was concerned with the presence or absence on the germinator of the organism Basisporium. One lot of 75 ears showed no evidence of Basisporium on either the sugary or the nonsugary kernels. When these ears were subjected to Gibberella the resistance index of the nonsugary class exceeded that of the sugary by 0.84 of a unit. Another group showed Basisporium present on both the nonsugary and sugary kernels on the germinator. When subjected to Gibberella inoculation a higher resistance index by 0.65 of a unit was exhibited by the nonsugary over that of the sugary class.

TABLE 1.—*Differences in relative resistance of nonsugary and sugary kernels of segregating ears to Gibberella saubinetii. Ears grouped according to the presence or absence of certain seed-borne organisms*

Group No.	Seed-borne organism	Organism present on nonsugary (Su[a])	Organism present on sugary (su[a])	Number of comparisons	Greater resistance shown by	Resistance greater by	Significance of difference as determined from value of P[b]
1	Not considered	.....	.....	126	Nonsugary	0.92	P = <0.01
2	Gibberella	No	No	84	Nonsugary	.98	P = < .01
3	"	Yes	"	14	"	.98	P = < .01
4	"	No	Yes	18	"	.79	P = < .01
5	"	Yes	"	10	"	.40	P = < .20
6	Penicillium	No	No	21	Nonsugary	.68	P = < .02
7	"	Yes	"	19	"	.74	P = < .04
8	"	No	Yes	24	"	1.40	P = < .01
9	"	Yes	"	60	"	.88	P = < .01
10	Basisporium	No	No	75	Nonsugary	.84	P = < .01
11	"	Yes	Yes	15	"	.65	P = < .02
12	Rhizopus	No	No	72	Nonsugary	.77	P = < .01
13	"	Yes	Yes	27	"	.98	P = < .01

[a] The genetic symbol Su indicates nonsugary (starchy) kernel; su, sugary (sweet) kernel.

[b] From Fisher's Probability Table (table of *t*).

In Fisher's table of *t* 0.05 may be taken as the upper limit of the significance of a difference.

The organism Rhizopus was considered in connection with two lots of ears. One lot of 72 ears showed no Rhizopus on the germinator on either the nonsugary or sugary kernels. When subjected to Gibberella inoculum the nonsugary seedlings showed a higher resistance to the organism, the difference being 0.77 of a unit. The second lot, composed of 27 ears, showed Rhizopus present on both the sugary and the nonsugary kernels on the germinator. A higher resistance to Gibberella infection by 0.98 of a unit was shown by the nonsugary over the sugary class of kernels.

Ears exhibiting 100 per cent germination as well as showing healthy seedlings on the germinator and on the control bench were considered alone in a group. Of all the ears tested only 4 showed this disease-free condition. The nonsugary seedlings gave a higher resistance index than the sugary seedlings by 0.40 of a unit.

Seedling vigor. A test was made to determine whether vigor, as expressed on the germinator by amount of growth of seedling, might influence resistance to Gibberella. These results are shown in table 2. Both classes of seedlings from one group of 40 ears were rated as "strong." Upon testing these ears against the seedling-blight organism, the resistance index of the nonsugary seedlings exceeds that of the sugary seedlings by 0.62 of a unit. A similar study was made using those ears from which the sugary and the nonsugary seedlings were both rated as "weak" on the germinator. On subjecting these ears to Gibberella inoculation, a difference of 0.55 of a unit was found in the resistance indices of the two types of kernels, the difference being in favor of the nonsugary type.

Reciprocal crosses. Reciprocal crosses were made between 4 nonsugary and 4 sugary plants. Since the genetic make-up of the seeds on the reciprocally pollinated ears would, on the average, be similar, the opportunity was presented to test the effect of the parental type, sugary or nonsugary, on resistance. It was necessary, of course, to compare the non-sugary kernels from the heterozygous plant with the corresponding class from the sugary plant. The sugary kernels from the 2 types of plants likewise were compared. The results are shown in table 3.

When the nonsugary kernels from the two classes of parent plants were tested a difference in the index resistance of 0.47 of a unit was found, the greater resistance being shown by the kernels that were borne on the heterozygous nonsugary plant. Considering the sugary class in the same manner, the higher index of resistance to Gibberella infection of 0.37 of a unit was shown by the kernels produced on the heterozygous nonsugary plant. Since the number of ears in each of these comparisons was limited, the results cannot be considered conclusive. They suggest, however, that the degree of resistance to Gibberella infection appears to be but little affected by the composition of the maternal parents as such with respect to the sugary and the nonsugary genes.

TABLE 2.—*Differences in relative resistance of nonsugary and sugary kernels of segregating ears to Gibberella saubinetii. Ears grouped according to the health and vigor of seedlings*

Group No.	Seedling characteristics	Comparisons made between		Number of comparisons	Greater resistance shown by	Resistance greater by	Significance of difference as determined from value of P[b]
1	All seedlings healthy 100 per cent germination	Nonsugary (Su[a])	Sugary (su[a])	4	Nonsugary	0.40	P = <0.40
2	Vigor of seedling	Nonsugary strong	Sugary strong	40	Nonsugary	.62	P = < .01
3	Vigor of seedling	Nonsugary weak	Sugary weak	11	Nonsugary	.55	P = < .20

[a] The genetic symbol Su indicates nonsugary (starchy) kernel; su, sugary (sweet) kernel.

[b] From Fisher's Probability Table (table of t).

In Fisher's table of t, 0.05 may be taken as the upper limit of the significance of a difference.

TABLE 3.—*Differences in relative resistance of nonsugary and sugary kernels to Gibberella saubinetii. Kernels were produced reciprocally on heterozygous nonsugary plants and on sugary plants*

Group No.	Type of kernels compared	Type of plant kernels were produced on—Comparisons made between		Number of comparisons made	Greater resistance shown by kernels produced on	Resistance greater by	Significance of difference as determined from value of P[b]
1	Nonsugary (Su)	Heterozygous nonsugary (Su[a]) plant	(Homozygous) sugary (su[a]) plant	4	Heterozygous nonsugary plant	0.47	P = 0.40
2	Sugary (su)	Heterozygous nonsugary (Su) plant	(Homozygous) sugary (su) plant	4	Heterozygous nonsugary plant	0.37	P = 0.40

[a] The genetic symbol Su indicates nonsugary (starchy) kernel; su indicates sugary (sweet) kernel.
[b] From Fisher's Probability Table (table of t).
In Fisher's table of t, 0.05 may be taken as the upper limit of the significance of a difference.

Kernel weight and resistance. A study was made to see if the weight of the kernel was correlated with the degree of resistance the seedling shows when subjected to Gibberella inoculation. It was also desired to know if such a correlation was higher in the nonsugary than in the sugary kernels.

Individual kernels were weighed to the nearest mgm. and grouped in 10 mgm. classes, the groups ranging from 80 to 370 mgm. All the kernels in a particular weight group were inoculated and planted together. The kernels from each ear were considered separately and the sugary and nonsugary kernels from the segregating ears were likewise considered as separate groups. Eighty to 100 kernels of each kind were tested from each ear. The average weights of the kernels that produced the seedlings in the various class groups were computed. The average kernel weights of each ear were arranged under the various resistance class groups. Very little, if any, correlation was found between the weight of the kernel and the degree of resistance the seedling grown from it exhibited when subjected to Gibberella inoculation. This appeared to be the case for both the sugary and the nonsugary kernels, regardless of whether they were produced on homozygous or on segregating ears. The groupings are shown in table 4.

DISCUSSION

Comparative studies between corn seedlings from sugary and nonsugary kernels with reference to their resistance to seedling blight caused by *Gibberella saubinetii* have been attempted in an effort to determine the effect the sugary gene exerts on resistance to the disease. By grouping the seedlings from the two kernel types into classes according to degree of infection and by the use of a resistance index, such studies are made possible.

It was not known what pathological influence any one of the seed-borne organisms concerned might have upon another when two were present together upon the same kernel. Several investigators have observed certain pathological influences among other organisms. Vasudeva (22), working with *Botrytis allii* and *Fusarium fructigenum* an apple tissue, found that the attack was much more reduced when both organisms were present than when only one was present. He states that the probabilities are that the effect is simply one of interference of one fungus with the growth of the other. Similar effects have been reported by other workers. Thus, Porter (19) claims that the attack of wheat by Helminthosporium and of flax by *F. lini* was reduced by the antagonistic action of a bacterium upon the fungus. Millard and Taylor (16) found that the presence of saprophytic species of Actinomyces markedly reduces the attack of potash-scab organism.

Various seed-borne organisms were found present on some of the corn kernels when examined on the germinator. Realizing this fact, it seemed

TABLE 4.—*Correlation—Weight of kernel and degree of resistance of the seedling to Gibberella saubinetii*[a]

Ear number	Kernel type	Classes showing graded scale of resistance (0–8)				
		Healthy seedlings Resistance value (8) Average weight of kernels	Mesocotyl-lesioned Resistance value (6) Average weight of kernels	Stelar-resistant Resistance value (4) Average weight of kernels	Blighted-after-emergence Resistance value (2) Average weight of kernels	Blighted before-emergence Resistance value (0) Average weight of kernels
Segregating Ears						
214–7	100 nonsugary	291	277	287	281	271
	80 sugary	252	259	263	266	253
214–26	100 nonsugary	.....	240	239	233	237
	80 sugary	.....	218	220	209	213
217–14	100 nonsugary	.....	334	345	325	316
	100 sugary	230	310	.....	250	271
197–30 × 207–21	100 nonsugary	.....	210	194	197	198
	100 sugary	170	184	174	184	187
215–20 × 208–9	100 nonsugary	240	222	219	225	226
	100 sugary	202	205	210	202	206
220–14 × 211–25	100 nonsugary	222	214	218	217	221
	100 sugary	210	212	207	201	199
Nonsugary Ears						
191–33	100 nonsugary	218	208	208	187	210
196–26	100 nonsugary	244	229	239	240	235
201–43	100 nonsugary	210	200	215	208	187
Sugary Ears						
209–1	80 sugary	170	233	238	226	230
210–2	100 sugary	.....	223	.....	218	227
212–34	100 sugary	120	117	118	108	121

[a] The figures in the resistance classes are the average weights of the kernels that produced the seedlings in those classes. Weights are recorded in mgm.

advisable to determine the various organisms on the ears and to analyze the data obtained from the kernels inoculated with Gibberella, accordingly.

When Gibberella was not observed as a seed-borne organism on either the sugary or nonsugary kernels, the nonsugary seedlings exhibited a resistance index greater by 0.98 of a unit than that of the sugary seedlings. Eighty-four ears were available for this comparison. The presence of the organism on the nonsugary but not on the sugary seeds resulted in no change in the average difference in resistance of the two classes of seedlings. When the organism was observed on the sugary but not on the nonsugary kernels on the germinator the greater resistance of the nonsugary over the sugary was slightly reduced, namely, to 0.79 of a unit. When the organism was present on both types the greater resistance of the nonsugary over the sugary was further reduced, this time to 0.40 of a unit. While the greater resistance index is again shown by the nonsugary kernels, this difference is possibly not statistically significant. However, this decrease in resistance of the nonsugary as compared with the sugary, when the organism was present on both types of kernels of the same ear, does not necessarily mean that the decrease is due to the effect of the seed-borne organism. The presence of Gibberella on the seed might be coincident with other factors that prevent the seedlings from the nonsugary and sugary kernels from giving expression to an inherent difference in resistance to seedling blight, even though such a difference might exist between the two types of kernels. It was found that, regardless of the presence or absence of Penicillium from the kernels of the segregating ears, in every case the resistance to Gibberella infection was higher in the nonsugary than in the sugary kernels. The differences in resistance of the two classes of seedlings ranged from 0.68 to 1.40 units.

It was found that when Basisporium was absent from both kernel types on the germinator, the nonsugary kernels showed a greater degree of resistance to Giberella infection by 0.84 of a unit. When Basisporium was present on both kernel types, the increased resistance of the nonsugary over the sugary was found to be slightly lower, 0.65 of a unit. With 15 comparisons, however, the higher resistance of the nonsugary kernels is probably significant. The decrease in resistance suggests that there might possibly be some influence exerted by Basisporium as a seed-borne organism. If such be the case in the groups of ears studied, the influence of Basisporium was not exerted to the point where an inherent difference in resistance of the nonsugary and sugary kernels to seedling blight was prevented from expressing itself.

Seventy-two ears showed no Rhizopus on the germinator on either type of kernel. When these were subjected to Gibberella inoculation, the non-

sugary seedlings exhibited a greater degree of resistance over the sugary by 0.77 of a unit. Another lot of 27 ears showed the organism present on both the nonsugary and sugary kernels. Under inoculation the nonsugary showed a greater index of resistance over the sugary by 0.98 of a unit. In view of these differences, Rhizopus seems to have no apparent effect upon the resistance of the 2 types of kernels to the seedling-blight organism.

In a group of 126 ears where no consideration was given to seed-borne organisms, a comparison was made between the resistance of the seedlings from the sugary and nonsugary kernels, to Gibberella infection. The nonsugary seedlings were found to exhibit a resistance index greater by 0.92 of a unit than that of the sugary seedlings. The difference is significant.

From the data presented regarding the influence of certain seed-borne organisms on resistance to seedling blight it is evident that a higher degree of resistance was shown by the nonsugary kernels in every group. In only one case was the difference not large enough to be considered significant. This was found where Gibberella was present on both the nonsugary and sugary kernels of the segregating ears. With 10 comparisons the resistance of the nonsugary was greater by 0.40 of a unit than that of the sugary. While this difference cannot be considered statistically significant, the greater resistance was still in favor of the nonsugary kernels.

Four segregating ears showed 100 per cent germination and all the seedlings were healthy on the control bench. When these were tested the nonsugary kernels showed a slightly higher index of resistance, greater by 0.40 of a unit. This small difference in resistance, obtained with 4 comparisons, indicates that the difference may not be significant. A possible explanation for the small difference with these apparently healthy ears is that the plants are inherently resistant, due to the presence of other genetic factors.

In the study of resistance where vigor of seedling was concerned, it was found that when the seedlings from the nonsugary and sugary kernels were rated as "strong" on the germinator, the nonsugary exceeded the sugary in resistance by 0.62 of a unit. This difference is based on 40 comparisons. When both types of kernels on the germinator were rated as "weak," the nonsugary again showed the greater degree of resistance; however, the difference was found to be reduced to 0.56 of a unit. In the group where the seedlings were rated as strong the greater resistance of the nonsugary was considered clearly significant, whereas in the group where the rating was weak the difference was reduced to a point that cannot be considered statistically significant. McIndoe (15) made observations on seedling vigor and resistance to Gibberella and found that in certain vigorous lines of corn factors for resistance were almost absent and no opportunity for variability existed.

The results obtained from tests with Gibberella do not indicate that the presence of the various seed-borne organisms found on the kernels materially affects the resistance of the nonsugary and sugary kernels to Gibberella infection. In every group of segregating ears studied the greater degree of resistance was shown by the nonsugary kernels. Only 3 groupings of ears showed differences in resistance indices that could not be considered statistically significant. In one of these both the sugary and nonsugary kernels were rated as weak on the germinator. In another group, composed of 10 ears, an examination of the records indicated that 80 per cent of the ears showed a seedling-vigor rating of weak and the other 20 per cent a rating of only "medium strong." It seems logical to conclude that, even though an inherent difference in degree of resistance should exist between the nonsugary and sugary kernels, the expression of such a difference might easily be covered up by factors making for a weakened condition of the seedlings. A third group that showed a small difference in resistance between the 2 classes of kernels was composed of ears that gave not only 100 per cent germination but of which all the seedlings were healthy on the control bench. This grouping is shown in table 2, group 1. Only 4 such ears were found and the difference of 0.40 in favor of the nonsugary kernels cannot be considered significant. It is possible that these ears possess other factors in their residual inheritance that are responsible for the slight difference in resistance between the nonsugary and sugary kernels.

When starchy and sweet corns are studied a number of differences are found to exist between them, some of which can be seen under a wide range of environmental influences, while others can be observed only under a particular set of environmental conditions. It has been shown that the expression of resistance of the nonsugary and sugary kernels to Gibberella seedling blight is dependent upon certain temperature relationships. Environmental factors are known to influence materially seedling growth and reactions. Kidd and West (13) have indicated that the growth of a plant directly produced from seed is a function of the early development of the seedling and have designated this relation as "physiological predetermination" of the seed or seedling. These workers found evidence that crops are directly influenced by the physiological condition of the seed and of the seedling, independently of their hereditary qualities. Environmental conditions that affect the parent may also markedly influence the subsequent course of development of the seed produced. The effects that become visible in one generation may have to be traced back to the external conditions that have operated in a previous generation.

A marked relationship between the environment during the period of maturation and the subsequent growth responses of the seedling has been

pointed out by Dickson and his coworkers (5). A strain of corn grown under an environment favorable for complete maturity produced ears resistant to seedling blight. The same strain, grown under unfavorable conditions for maturity, produced ears highly susceptible to blight. The genetic composition of the line apparently was not disturbed, but rather the expression of the characters. Under the two environmental conditions there were little differences in endosperm composition, but marked changes were found in the 2 embryos. Russell (20) reports similar responses with a strain of spring wheat.

Holbert and Burlison (9), in a study of cold resistance and susceptibility in inbred, crossbred, and open-pollinated strains of dent corn, found wide variations existing in resistance to cold injury as the corn approached maturity. Seed matured on plants high in cold resistance produced plants more resistant to Gibberella seedling blight than did seed gathered at the same time from corresponding plants previously injured by cold. According to Hoppe (12), some selfed strains of corn always show a high degree of resistance to Gibberella under a given range of environmental conditions, while other strains are highly susceptible. Strains were isolated that showed a consistent behavior at a given temperature. Eckerson and Dickson (6) have reported that seedlings grown at high soil temperatures are high in available carbohydrates and are low in available nitrogen. The cell walls are composed of pectic materials, cellulose being absent until photosynthesis begins. The parasite penetrates the walls of pectic materials apparently with little difficulty, whereas it penetrates the cellulose walls slowly. These workers state that these differences apparently explain in part the variation in susceptibility to Gibberella seedling blight. Later Dickson, Eckerson, and Link (4) added that, due to an abundance of sugar and dextrins available in the corn embryo at high temperatures, a carbohydrate reserve exists for building thicker and more resistant cell walls.

Through microchemical methods Toole (21) followed some of the histological and chemical changes taking place as germination progresses in the corn kernel. He concluded that the embryonic corn plant utilizes its own stored food for its initial growth before any change of food transfer takes place in the endosperm. He worked with dent corn. Similar studies on sweet corn should offer valuable data for a comparative study of the changes taking place in dent corn.

The ripening processes were studied by Appleman and Eaton (1), who state the sweet corn is considered ripe when the growth of the kernel ceases and the chemical changes have nearly attained equilibrium. They point out that the ripening process, being either chemical or dependent upon chemical processes, is influenced by the temperature prevailing during the ripening period.

Some observations at Madison, Wisconsin, upon segregating ears have suggested a differential rate of maturity of the sweet and starchy kernels upon the same ear. The temperature in a particular locality during the period of maturation might be such as to cause the metabolic processes to proceed in the starchy corn at a different rate from that in the sugary kernels. Should the rate of maturity in the sweet corn be lower than that in the starchy, a difference in degree of maturity at harvest might mean a decided difference in quality and in quantity of the reserve materials stored in the starchy and in the sugary kernels. Should the stored food in the kernel be of such a nature as not to promote favorable growth in the young seedling, the latter would likely be less fortified against the attacks of parasitic organisms.

The work of Pearson (18) has shown that corn seedlings may be attacked by Gibberella in the early period of germination. Should the rate of maturity be lower in the sugary than in the nonsugary kernels and the temperatures obtaining during the maturation period cause the sugary kernels to have an unbalanced food reserve at harvest time, the sugary kernels might be less fitted to resist the attacks of the organism.

The investigations reported in this paper show that a relatively greater degree of resistance to Gibberella seedling blight is exhibited by the nonsugary as compared with the sugary seedlings, regardless of the presence of certain seed-borne organisms. While starchy and sugary corns are known to differ in regard to endosperm reserves by a single genetic factor, there may also be a wide variation in composition with respect to other genetic factors. These factors are probably responsible to a considerable extent for the wide variations in resistance to seedling blight sometimes exhibited among different strains of the same type of corn. Their presence might explain in part the variations among the kernels of the same ear. McIndoe (15) studied the inheritance of the reaction of corn to Gibberella seedling blight. His work did not involve sweet corn but included 3 varieties of dent. His results led him to state that the inheritance of resistance is quantitative in nature and conditioned by multiple factors. Strains of corn differing widely in resistance to Gibberella were involved in his work. He further suggests that the number of genetic factors involving resistance is perhaps relatively few, since he was able to recover in the F_3 generation highly resistant and susceptible lines from crosses involving lines that differed widely in resistance.

If resistance to Gibberella seedling blight is conditioned by multiple factors, it is probable that the sugary gene differentiating the nonsugary and sugary kernels is one of the number of factors responsible for the difference in degree of resistance of the two types of kernels to the seedling-

blight disease. Resistance being dependent upon multiple factors, wide variations in resistance are to be expected in various strains of corn. However, since the sugary gene tends to bring about a lowered resistance, one cannot hope to obtain in sweet corn the high degree of resistance that is possible among the starchy corns.

SUMMARY

1. In an attempt to study the effect of the sugary gene in corn on resistance to seedling blight caused by *Gibberella saubinetii*, comparative tests were made between the sweet and starchy kernels produced on the same segregating ear.

2. The segregating ears were grouped according to the presence or absence of 4 commonly found organisms on the seed: Gibberella, Penicillium, Rhizopus, and Basisporium. The effects of these seed-borne organisms were studied to see if the presence of the fungi would materially affect the degree of resistance of the kernels to seedling blight.

3. Very little, if any, preference appeared to be exhibited by any of the 4 seed-borne organisms for the sugary or nonsugary kernels, one over the other.

4. In every group of segregating ears, the higher index of resistance to seedling blight was shown by the nonsugary kernels. In only one case was the difference not great enough to be considered statistically significant. Such a case was found where the seed-borne organism, Gibberella, was present on both the nonsugary and the sugary kernels of the segregating ears.

5. In a group of 4 ears showing 100 per cent germination and all healthy seedlings on germinator, very little difference in resistance was found between the nonsugary and the sugary kernels. A possible explanation is that other genetic factors account for the small difference in resistance.

6. When the sugary and nonsugary kernels on the germinator produced seedlings that were rated as strong a significantly greater degree of resistance to Gibberella infection was shown by the nonsugary kernels. When both types of seedlings were rated as weak the resistance index of the nonsugary was not sufficiently higher than that of the sugary to be considered significant.

7. Very little, if any, correlation was found to exist between the weight of the kernel and the degree of resistance the seedling grown from it exhibited when subjected to Gibberella infection. This appears to be the case for both the nonsugary and the sugary kernels, regardless of whether they are produced on homozygous nonsugary or on segregating ears.

8. It is apparent from the results obtained that the sugary gene, which differentiates the sugary and nonsugary kernels, is also a factor responsible

for the differential resistance exhibited between the 2 kernel types to seedling-blight disease.

9. The sugary gene in itself lowers resistance to seedling blight and hence is a limiting factor in the production of a sweet corn possessing the same high degree of resistance found in certain strains of starchy corn.

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LITERATURE CITED

1. APPLEMAN, C. A., and S. V. EATON. Evaluation of climatic temperature efficiency for the ripening processes in sweetcorn. Jour. Agr. Res. **20**: 795–805. 1921.
2. CORRENS, C. Bastarde zwischen Maisrassen, mit besonderer Berücksichtigung der Xenien. 161 pp. E. Nägeli, Stuttgart. (Bibliotheca Botanica heft 53). 1901.
3. DICKSON, J. G. The influence of soil temperature and moisture on the development of the seedling blight of wheat and corn caused by *Gibberella saubinetii*. Jour. Agr Res. **23**: 837–870. 1923.
4. ————, S. H. ECKERSON, and K. P. LINK. The nature of resistance to seedling blight of cereals. Proc. Nat. Acad. Sci. **9**: 434–439. 1923.
5. ————, P. E. HOPPE, J. R. HOLBERT, and GEO. JANSSEN. The influence of environment during maturation upon predisposition to seedling blight in wheat and corn strains. (Abst.) Phytopath. **19**: 79. 1929.
6. ECKERSON, S. H., and J. G. DICKSON. The influence of soil temperature and moisture on the chemical composition of wheat and corn and their predisposition to seedling blight. (Abst.) Phytopath. **13**: 50–51. 1923.
7. FISHER, R. A. Statistical methods for research workers. 3. ed. 283 pp. Oliver and Boyd Publishing Company, Edinburgh. 1930.
8. HOFFER, G. N., and J. R. HOLBERT. Selection of disease-free seed corn. Purdue Univ. Agr. Exp. Sta. Bul. 224. 1918.
9. HOLBERT, J. R., and W. L. BURLISON. Studies of cold resistance and susceptibility in corn. (Abst.) Phytopath. **19**: 105–106. 1929.
10. ————, and G. N. HOFFER. Control of the root, stalk, and ear rot diseases of corn. U. S. Dept. Agr. Farmers Bul. 1176. 1920.
11. ————, W. L. BURLISON, B. KOEHLER, C. M. WOODWORTH, and G. H. DUNGAN. Corn root, stalk, and ear rot diseases, and their control through seed selection and breeding. Ill. Agr. Exp. Sta. Bul. 255: 239–478. 1924.
12. HOPPE, P. E. Inheritance of resistance to seedling blight of corn caused by *Gibberella saubinetii*. (Abst.) Phytopath. **19**: 79–80. 1929.
13. KIDD, F., and C. WEST. Physiological predetermination: The influence of the physiological condition of the seed upon the course of subsequent growth and upon the yield. Ann. Appl. Biol. **5**: 1–10, 112–142, 157–170, 220–251; **6**: 1–26. 1918–19.
14. KOEHLER, B., and J. R. HOLBERT. Corn diseases in Illinois—their extent, nature, and control. Ill. Agr. Exp. Sta. Bul. 354. 1930.
15. MCINDOE, K. G. The inheritance of the reaction of maize to *Gibberella saubinetii*. Phytopath. **21**: 615–639. 1931.
16. MILLARD, W. A., and C. B. TAYLOR. Antagonism of micro-organisms as the controlling factor in the inhibition of scab by green-manuring. Ann. Appl. Biol. **14**: 202–216. 1927.

17. MOORE, W. D. Corn root and ear rot studies. New Jersey Agr. Exp. Sta. Ann. Rpt. 44: 404–407. 1924.
18. PEARSON, N. L. Parasitism of *Gibberella saubinetii* on corn seedlings. Jour. Agr. Res. 43: 569–596. 1931.
19. PORTER, C. L. Concerning the characters of certain fungi as exhibited by their growth in the presence of other fungi. Amer. Jour. Bot. 11: 168–188. 1924.
20. RUSSELL, H. L. Disease resistance and yield influenced by climate where seed was grown. Wis. Agr. Exp. Sta. Ann. Rpt. 1927–1928; (Bul. 405): 86–87. 1929.
21. TOOLE, E. H. The transformations and course of development of germinating maize. Amer. Jour. Bot. 11: 325–350. 1924.
22. VASUDEVA, R. S. Studies in the physiology of parasitism. XII. On the effect of one organism in reducing the parasitic activity of another. Ann. Bot. 44: 557–564. 1930.

CARBOHYDRATE FERMENTATION BY CERTAIN CLOSELY RELATED SPECIES IN THE GENUS PHYTOMONAS

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The present work was begun with the purpose of differentiating between the 3 bacterial pathogens, *Phytomonas phaseoli* (E. F. Sm.) Bergey *et al.*, *Phyt. phaseoli* var. *sojense*, and *Phyt. phaseoli* var. *fuscans* by their ability to ferment various carbohydrates. The first 2 pathogens have never been separated in pure culture on any of their biochemical reactions, and the last-named variety is distinguished from the other 2 only by its ability to ferment the amino-acid tyrosine. The investigation, after it was begun, was expanded to include 6 other closely related species that the writer, in his article in this journal for January, 1930, had placed in what he called the *campestre* group in the genus Phytomonas.

Certain reasons made it desirable to study the carbohydrate fermentation of this group of organisms. In ordinary media, especially those containing beef extract, peptone, or other protein digests, these species produce a strong alkali. This characteristic has interfered in the past with correctly interpreting the results of carbohydrate fermentation with the ordinary methods used. These methods, in the main, have consisted in growing the bacteria in beef-extract-peptone broth to which the carbon source has been added. If an acid or gas is produced, the carbohydrate is considered to have been fermented, but, if the hydrogen-ion concentration of the medium remains stationary or moves to the alkaline side of neutrality, a negative reaction is recorded. The members of the *campestre* group, however, produce a strong alkali and immediately neutralize any acid that is formed, and many of the carbohydrates that in reality are fermented have not been so recorded. This has resulted in inconsistencies in the description of certain of the pathogens. These inconsistencies, however, in many cases may be readily discerned. For instance, a number of the species have been described as fermenting starch and not fermenting any of the monosaccharides, which is contrary to the so-called theory of carbohydrate gradients. Glucose, even, has shown no signs of being fermented, and, according to Kendall (4), "no authentic instance has been recorded in which a microbe utilizes any carbohydrate for energy that will not utilize glucose."

Furthermore, since such characteristics as indol and hydrogen sulphide production, gelatin liquefaction, nitrate reduction, and the morphology of the species are identical, one must turn to carbohydrate fermentation to separate the species in culture. For this reason the data should be accurate and only reliable methods should be employed.

PATHOGENS USED IN THESE EXPERIMENTS

Nine species and varieties of the genus Phytomonas were tested in this investigation for their ability to ferment various carbohydrates. In certain cases duplicate strains were used. As far as the writer is aware, no extensive and careful work has been conducted on the fermenting ability of these organisms with the exception of the work of Lewis (5) on the species *Phyt. malvacearum.*

The pathogens used in the present comparative study were as follows and, unless otherwise stated, were isolated by the writer. Duplicate strains when used also are recorded.

Phytomonas campestris (Pammel) Bergey *et al.* isolated August, 1929, from cauliflower leaves.

Phyt. juglandis (Pierce) Bergey *et al.* isolated by P. W. Miller and received from H. P. Barss, March 14, 1930.

Phyt. malvacearum E. F. Sm., Bergey *et al.* isolated 1923 and received from the Bureau of Plant Industry, March, 1930.

Phyt. malvacearum isolated October, 1931, from diseased cotton leaves received from South Carolina.

Phyt. phaseoli isolated October, 1927, from bean pods collected in Switzerland.

Phyt. phaseoli isolated April, 1930, from bean seed collected at Clifton Springs, New York, in 1923.

Phyt. phaseoli var. *fuscans* isolated December, 1924, from bean leaves collected in Switzerland.

Phyt. phaseoli var. *fuscans* isolated October, 1927, from bean pods collected in Switzerland.

Phyt. phaseoli var. *sojense* (2 cultures) received from Florence Hedges, March, 1930.

Phyt. vascularum (Cobb) Bergey *et al.* isolated 1923 and received from the Bureau of Plant Industry, March, 1930.

Phyt. vesicatoria (Doidge) Bergey *et al.* isolated from diseased tomato fruits at Ithaca, N. Y., August, 1929.

Phyt. vitians (Brown) Bergey *et al.* isolated 1917 and received from the Bureau of Plant Industry, March, 1930.

Other species and varieties belonging to the *campestre* group, but, for various reasons, not included in the present investigation, are *Phytomonas campestris* var. *armoraciae* (McCulloch) Bergey *et al.*, *Phyt. citri* (Hasse) Bergey *et al.*, *Phyt. cucurbitae* (Bryan) Bergey *et al.*, *Phyt. papavericola,* and *Phyt. vesicatoria* var. *raphani* (White). This list, no doubt, does not include all the members of the group, but meager and inadequate descriptions of many species make their placing difficult.

The 9 species and varieties used in the present fermentation studies, when grown in pure culture, were surprisingly similar in appearance. On beef-extract agar (pH 7.0) growth was good, filiform, and amber yellow to primuline yellow. On an agar medium containing dextrose, sucrose, and certain other sugars, a large amount of gum was produced giving the growth a syrupy appearance. This gum production in culture possibly gives a clue to the so-called zoogloea found in nature. *Phytomonas vitians,* alone, did not possess this characteristic. With the exception of this dissimilarity, however, the differences in appearance between any of the species and varieties were never greater than the differences noted between the 2 strains of *Phyt. phaseoli* used in the experiments.

Before conducting the fermentation experiments the pathogenicity of each organism was proved with the exception of *Phytomonas juglandis* and *Phyt. vitians.* With the former it was difficult under the conditions to obtain growing walnut trees of susceptible varieties. Lettuce, however, was inoculated with *Phyt. vitians,* but infection did not take place. Either the conditions were unfavorable, or the pathogen had become nonvirulent from many years' growth in culture.

METHODS

To determine the fermentation ability of these 9 bacterial pathogens a synthetic peptone-free base was used to which the various carbohydrates were added. It was fortunate in this respect that none of the bacteria being studied required an organic source of nitrogen but could utilize an ammonium salt. Two different basic media were employed and contained no amino acid that could be converted into ammonia. When the salts of organic acids were being tested, the medium and methods recommended by Ayers, Rupp, and Johnson (1) for alkali-forming bacteria were followed. In this case only 0.15 per cent of the salt was added to a synthetic liquid base. With the sugars, alcohols, and glucocides a slightly modified formula of the above medium was used and is the one recommended in the *Manual of Methods of Pure Culture Study of Bacteria* issued by the Society of American Bacteriologists (7). One per cent of sugar or other carbon source was added to the synthetic base and used as a solid medium with the addition of agar. In both cases the medium was adjusted to approximately pH 7 by the addition of sodium hydroxide, and brom-cresol purple was added as an indicator. All media, unless otherwise stated, were sterilized at 15-lbs. pressure for 18 minutes.

The ability of each organism to ferment the following carbohydrates was tested in media made in the above manner: dextrose, levulose, galactose, arabinose, xylose, rhamnose, lactose, maltose, sucrose, raffinose, dulcitol,

glycerol, mannitol, salicin, and the sodium salts of acetic, benzoic, citric, formic, malic, salicylic, succinic, and tartaric acids.

Since the sugars, levulose, lactose, maltose, sucrose, and raffinose have a tendency either to carbonize or to break down into monosaccharides when heated, a liquid medium also was prepared in which these sugars were sterilized by filtration. In this case a 10 per cent solution of the sugar was filtered through a Berkefeld filter and 1 cc. of the solution was added to tubes containing approximately 9 cc. of the sterilized basic medium. Such media were incubated for several days at 27° C. to insure their sterility before using.

In determining the hydrolysis of starch, the starch-agar-iodine method was used. Since it frequently is difficult to obtain soluble starch free from impurities, this direct method is more satisfactory than the indirect method of testing for acid production. Similarly, a direct method was employed in testing for the hydrolysis of cellulose. Strips of filter paper were added to test-tubes that in one series contained approximately 5 cc. of Dunham's solution and in another series contained the modified Ayers, Rupp, and Johnson solution.

The organisms to be tested were grown first on beef-extract agar for approximately 48 hours and then transferred to the carbohydrate media. Three tubes of each medium were used and were incubated at 27° C.

Since, with the exception of the starch and cellulose media, the only source of energy for the bacteria was the added carbohydrate, fermentation could be determined by growth alone. Fermentation, however, was always accompanied by a change of hydrogen-ion concentration. When any of the sugars, alcohols, or glucosides were fermented, the production of an acid soon changed the color of the medium from purple to yellow. With the organic acid salts, however, there was a rise in pH, showing a considerable production of alkali. According to Ayers, Rupp, and Johnson (1), these salts are fermented into carbonates.

Diastase production was not considered positive unless there was a definite visible zone about the streaks in the plate when the iodine solution was added. A slight decomposition of starch, visible only by the aid of the microscope, might be due to an acid hydrolysis and has been disregarded. Likewise, only a visible decomposition of the filter paper has been considered a positive hydrolysis of cellulose.

RESULTS OF FERMENTATION STUDIES

The data gathered from these fermentation studies have been arranged in table 1. In the majority of cases the ability of the organism to ferment a sugar or not was clear-cut, and there could be no doubt as to the inter-

TABLE 1.—*Showing the carbohydrates fermented by 8 species and varieties of a closely related group in the genus Phytomonas*[a]

	Dextrose	Levulose	Galactose	Arabinose	Xylose	Rhamnose	Lactose	Maltose	Sucrose	Raffinose	Dulcitol	Glycerol	Mannitol	Salicin	Starch	Cellulose	Acetic acid	Benzoic acid	Citric acid	Formic acid	Malic acid	Salicylic acid	Succinic acid	Tartaric acid
Phytomonas campestre	+	+	+	+	+	−	−	+	+	+	−	+	+	−	+	−	+	−	+	−	+	−	+	−
Phytomonas juglandis	+	+	+	+	+	−	+	+	+	+	−	+	+	−	+	−	+	−	+	−	+	−	+	−
Phytomonas malvacearum	+	+	+	−	+	−	+	+	+	+	−	+	−	−	+	−	+	−	+	−	+	−	+	−
Phytomonas phaseoli	+	+	+	+	+	−	+	+	+	+	−	+	−	−	+	−	+	−	+	−	+	−	+	−
Phytomonas phaseoli var. fuscans	+	+	+	+	+	−	+	−	+	+	−	+	+	−	+	−	+	−	+	−	+	−	+	−
Phytomonas phaseoli var. sojense	+	+	+	+	+	−	+	+	+	+	−	+	+	−	+	−	+	−	+	−	+	−	+	−
Phytomonas vascularum	+	+	+	−	+	−	−	−	+	+	−	−	−	−	+	−	+	−	+	−	+	−	+	−
Phytomonas vesicatoria	+	+	+	+	+	−	?	+	+	+	−	+	+	−	+	−	+	−	+	−	+	−	+	−
Phytomonas vitians	+	+	+	+	+	−	+	−	+	+	−	+	+	−	−	−	+	−	+	−	+	−	+	−

[a] A plus sign means fermentation; a minus sign, no fermentation.

pretation. A few exceptions, however, were noted and are here presented. In media to which rhamnose, dulcitol, and salicin had been added, all organisms gave a trace of growth. After 2 months, however the hydrogen-ion concentration in these cultures had not changed appreciably, and it was considered that these 3 carbohydrates contained a slight quantity of impurities that permitted growth.

In considering the sugars that were filtered it should be stated that there existed no differences between them and the heated sugars with the exception of lactose and maltose. *Phytomonas campestre* and *Phyt. vascularum* grew and produced an acid in the heated lactose, but in the filtered sugar *Phyt. vascularum* did not grow, and only in several instances was there any growth of *Phyt. campestre.* In the latter case growth occurred 2 or 3 weeks after the organisms had been transferred to the tubes. From the table it may be seen that 3 of the organisms do not ferment maltose either in the heated or filtered condition. *Phytomonas malvacearum,* however, fermented filtered maltose but did not at all or only slightly ferment the heated sugar. On first thought this behavior appears extraordinary, but Lewis (6) has shown that this species is very sensitive to overheated sugars.

In a few cases the present study in carbohydrate fermentation does not agree with certain previous work. Negative results where peptone has been used as a base naturally have not been considered. Elliott (2) states that *Phytomons campestre* does not ferment maltose but that lactose is fermented. In the present investigations, the reverse was found to be true. The use of heated and filtered sugars might have something to do with this discrepancy or various physiologic races of the pathogen may exist.

Phytomonas malvacearum varies from the description given by Lewis (5) in that arabinose was fermented by one of the strains studied. The fermentation was slow in the liquid medium but very good on the agar medium. This characteristic probably is a variation from the normal since it occurred in only one strain of the organism in this investigation and was not found by Lewis in any of the 14 strains he studied.

In examining table 1 it may be seen that certain of the pathogens can be differentiated by their ability to ferment carbohydrates, especially sugars and alcohols. The glucocides, the polysaccharides, and the salts of the 8 organic acids were of little help. With one exception they were utilized either by all the pathogens or by none.

Phytomonas phaseoli var. *fuscans, Phyt. vascularum,* and *Phyt. vitians* are separated from the other members of the group by their inability to ferment maltose. Of these organisms *Phyt. vitians* alone does not hydrolyze starch. This characteristic and the fact that the organism does not produce

gum in culture separate it rather sharply from the remainder of the group. *Phytomonas vascularum* ferments relatively few carbohydrates, which distinguishes it; especially noticeable in this respect is its inability to utilize arabinose, lactose, and glycerol.

Among the 6 maltose fermenters it is of special interest to note that *Phytomonas phaseoli* var. *sojense* can be differentiated from *Phyt. phaseoli* by its ability to utilize the alcohol, mannitol. This test was repeated several times with 2 different strains of each pathogen, and it appears to be a clear-cut distinction. *Phytomonas campestre, Phyt. juglandis, Phyt. phaseoli* var. *sojense,* and *Phyt. vesicatoria* are not so easily separated. *Phytomonas campestre* usually does not ferment lactose, and this characteristic would separate it from the remaining maltose-fermenting pathogens. The test, however, is a delicate one, and further work should be done on a large number of strains of the pathogen before accepting this as a definite means of separation. *Phytomonas malvacearum* can be separated from *Phyt. phaseoli* only by its inability to ferment arabinose, and here certain anomalies might exist. These 2 pathogens are distinct from the remaining maltose fermenters in their inability to utilize mannitol.

A further separation of the group on the basis of the carbohydrates used is not possible. While a definite step has been made in the study of the carbohydrate fermentation of this group and the separation of the species, the problem is by no means solved. More intensive work on the individual species in which many strains are employed is needed together with further comparative studies with other carbohydrates. It is clear, nevertheless, that culturally the pathogens are very closely related, and, no doubt, if their relationship had been appreciated at the time each pathogen was described, there would have been but one species with many varieties. That they should be reduced to varieties now, however, is by no means desirable since the names are so well established in literature.

Alkali Production. According to Elliott (2), in the preface to her manual, the alkali produced by this group is ammonia. On the other hand, Ayers, Rupp, and Johnson (1) have stated that certain bacteria produce quantities of carbonates and bicarbonates from the fermentation of organic acids and thus may neutralize any acid produced from sugars or other common carbohydrates.

Certain experiments, therefore, were conducted to determine, if possible, the nature of this alkali and from what source it was formed. First, a comparative study was made of dextrose fermentation in the synthetic medium used above and in a beef-extract-peptone base. In the former case, all the bacteria turned the brom cresol purple indicator to a distinct yellow in approximately 48 hours. In the latter case where Andrade's

indicator was used instead of the brom cresol purple, a good growth was obtained within 24 hours, but at no time did the medium turn red to indicate production of acid. It was evident that a neutralization of the acid formed from the sugar was taking place.

Tests then were made for ammonia following the method advocated by Hanson (3). The bacteria were grown on Hucker's agar and in all cases there was a strong ammonium reaction. Tests also were made with the various organisms in standard beef-extract bouillon (pH 7.25), in a 0.5 per cent peptone broth (pH 7.20), and in a 0.3 per cent beef-extract broth (pH 7.25), and again ammonia was formed in all the tubes. In the peptone broth, after 48 hours' growth of the bacteria, the alkalinity rose from an initial pH 7.20 to a minimum pH 7.32 and a maximum pH 7.50. This rise probably was due entirely to the ammonia production, since the intensity of the color in the reaction varied with the pH of the culture medium. A continued production of this amount of ammonia for several days, without doubt, would neutralize any acid produced from sugar fermentation and render worthless a color indicator.

While the ammonia doubtless plays a large part in neutralizing acids produced from carbohydrate fermentation, in the presence of organic nitrogen, the alkali formed in the fermentation of organic acids should not be overlooked. Ayers, Rupp, and Johnson (1) are of the opinion that this is the chief source of alkali produced by a group of bacteria isolated from milk. They were able to show that the carbonates produced by the fermentation of the citric acid in milk were sufficient to neutralize the acid produced in the fermentation of milk sugars. The citric acid was broken down into carbonates. In the present investigation it is shown that these plant pathogens were able to ferment the salts of acetic, citric, malic, and succinic acids. Doubtless other acids exist that they are able to utilize. A very small amount of the salt was added to the media, 0.15 per cent to be exact; yet considerable alkali was produced upon fermentation. In the acetic acid medium the alkalinity within a week rose from a pH 7.00 to between pH 7.10 and pH 8.27, according to the species or culture tested. In the citric acid medium the rise in the same length of time was from an initial pH 6.90 to between pH 7.00 and pH 7.55; in the malic acid medium the rise was from an initial pH 6.80 to between pH 7.60 and pH 7.80; and in the succinic acid medium the rise was from an initial pH 6.71 to between pH 6.81 and pH 7.61.

It may be seen from these experiments that considerable alkali is formed from the organic acids in a solution of only 0.15 per cent. Whether or not the salts of these acids are present in beef extract and to what extent they are present in such media have not been determined by the writer. Also,

whether or not the organic acids that are the result of sugar fermentation are the end-products of the reaction or are utilized further is not known. This phase of the subject should be investigated before one concludes that the neutralizing alkali in the sugar-broth cultures is due to something more than ammonia.

SUMMARY

The fermenting ability of 9 species and varieties in the genus Phytomonas has been investigated. Twenty-four different carbohydrates were used.

It has been pointed out that accurate results are not to be expected when the sugar or other carbon source to be tested is added to beef-extract-peptone broth. In this medium the pathogens produce a strong alkali, which neutralizes any acid formed through sugar fermentation. This alkali is ammonia produced from protein digests and possibly carbonates produced from fermentation of organic acid.

Five of the pathogens may be definitely differentiated by their ability to ferment certain of the carbohydrates.

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LITERATURE CITED

1. AYERS, S. H., P. RUPP, and W. T. JOHNSON, JR. A study of the alkali-forming bacteria found in milk. U. S. Dept. Agr. Bul. 782. 1919.
2. ELLIOTT, CHARLOTTE. Manual of bacterial plant pathogens. The Williams and Wilkins Company, Baltimore. 349 pp. 1930.
3. HANSON, P. ARNE. The detection of ammonia production by bacteria in agar slants. Jour. Bact. **19**: 223–229. 1930.
4. KENDALL, A. I. The utilization of carbohydrates by bacteria. *In* Jordan and Falk, The newer knowledge of bacteriology and immunology. pp. 227–242. Univ. Chicago Press. 1928.
5. LEWIS, I. M. Growth of plant pathogenic bacteria in synthetic culture media with special reference to *Phytomonas malvaceara*. Phytopath. **20**: 723–731. 1930.
6. ————. The inhibition of *Phytomonas malvaceara* in culture media containing sugars. Jour. Bact. **19**: 423–433. 1930.
7. Society of American Bacteriologists, Committee on Bacteriological Technique. Manual of methods for pure culture study of bacteria. The Society, Geneva, N. Y. 1923–1931.

CRINKLE DISEASE OF STRAWBERRY[1]

S. M. Zeller and E. K. Vaughan

The "crinkle" disease of strawberry was first noticed by C. E. Schuster and the senior writer in 1925.[2] Since that time the name crinkle has been applied to this disorder in California and Oregon.

In the Pacific Northwest the disease is wide-spread in the Marshall type of strawberry. Any quantity of stock of this variety entirely free from crinkle in western Oregon is rarely found. Other varieties as a rule are quite free from it, but they may in time show the symptoms when planted in close proximity to diseased Marshalls. Other varieties in which the symptoms have been noted are Corvallis, Dunlap, Gene, Sear's La Grange, Magoon, Missionary, Nick Ohmer, Norwood, O. S. C. No. 7, Howard 17 (Premier), Redheart (U. S. D. A. No. 632), U. S. D. A. Nos. 227-A, 400, 520, and 682. Occasional plants of the Ettersburg No. 121 and Clark Seedling affected with similar symptoms have been observed.

For the most part the effects of the disease have not been severe enough to arouse the concern of growers. Affected plants are not killed. They continue to yield, although the quantity of crop is doubtless not up to standard. The disease probably does not rank in destruction with root weevil, crown borer, or Rhizoctonia. Its general appearance and behavior are distinct from those of the other pests and diseases under like conditions.

Crinkle has the general appearance and behavior of a virous disease. It is perhaps more nearly like the yellows (xanthosis)[3] than any other described strawberry disease.

In his reported occurrence of yellows in Oregon,[4] Plakidas may have been mistaken. It now seems more probable that the disease observed and reported by him was, in fact, crinkle. Yellows is evidently quite restricted to California and in some scattered stocks originating from that State. It does not occur generally in Oregon, so far as the writers are aware, but has been seen in a few cases where it may have been introduced on planting stock from California. These cases have been cleaned up. Crinkle, on the other hand, is widely distributed in the Pacific Northwest and probably has spread into California through planting stock. Its origin, of course, is unknown.

[1] Published as Technical Paper No. 177 with the approval of the Director of the Oregon Agricultural Experiment Station. Contribution from the Department of Botany and Plant Pathology.

[2] Oregon Agr. Exp. Sta., Bienn. Rpt. 1924–1926: 94. 1926.

[3] Plakidas, A. G. Strawberry xanthosis (yellows), a new insect-borne disease. Jour. Agr. Res. 35: 1057–1090. 1927.

[4] *Loc. cit.*, p. 1061.

Although no one person has studied crinkle throughout its known north and south range, it would seem from the observations of several workers that the symptoms are more evident in the growing season toward the southern limits of this range.

The two most characteristic symptoms are the crinkled condition and chlorotic character of the leaves. The former is undoubtedly due to the uneven distribution of the chlorotic areas in the early stages of leaf development. The rugose condition of the leaf surface seems to follow the chlorotic areas with no distinct pattern. (Fig. 1.)

These chlorotic areas at first are extremely localized, starting in very small, developing leaves as mere pin-point areas and expanding somewhat with leaf expansion. By transmitted light these areas show up plainly. Often the extremely chlorotic centers of these yellowed spots become necrotic, at first reddened and then brownish dead tissue resulting. It is not uncommon to find smaller leaves with many necrotic centers during the less favorable growing conditions from September to March. Besides this stippling, some leaflets exhibit most uneven chlorosis. As a rule, leaflets are yellower toward the margins. This yellowing may extend in streaks along a certain few veins toward the midrib. On the other hand, the veins, for the most part, may become "cleared." This may extend even into the finely netted venation. Together with the resultant shortening of veins, there may be more or less normal growth in the neighboring green tissues, producing various degrees of crinkled leaf surface.

With the uneven distribution of growth there results an uneven margin of the leaflets. The more or less regular dentation becomes a deeper crenation and an unnatural wavy lobing of the margins.

During any season of the year the whole of an affected plant is a lighter shade of green than normal. In the greenhouse, or in the field during late fall and winter plants lose most of their erect growth. The leaves produced under these conditions have short petioles, the whole plant presenting a flattened appearance. During favorable growing periods the affected plants may grow out of most of the symptoms and yet retain some characters to distinguish them from healthy plants. The leaves under these most favorable conditions do not have quite the uniform greenness and smooth surface exhibited by normal leaves, and there is a tendency for the leaves to arch downward or cup upward at the margins.

In late fall and winter the runner plants may show symptoms as characteristically as the parent plant. This is not always true in very fertile soils, as pointed out in more detail below. All affected varieties that have been observed with runner plants have shown the symptoms in the latter, and exceptionally well in runner plants of the Corvallis, Magoon, Marshall, Nick Ohmer, and Norwood.

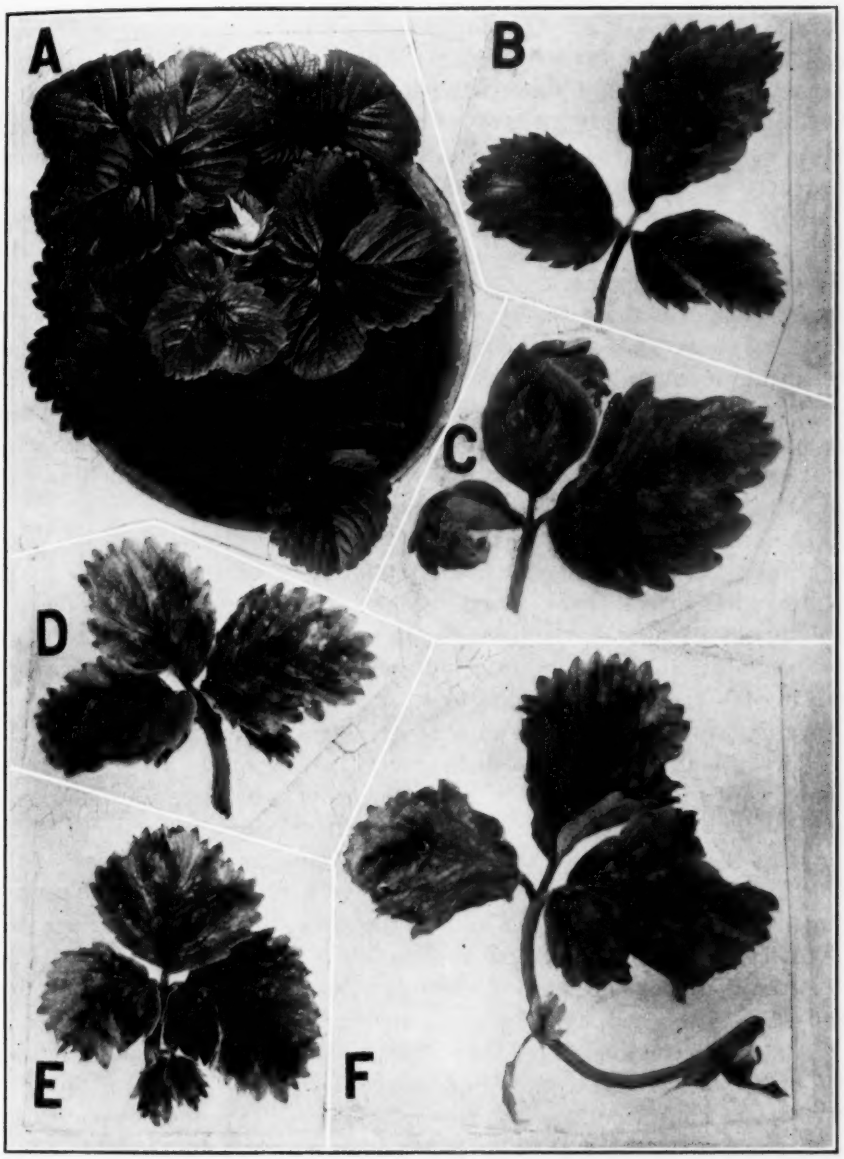

FIG. 1. A. Healthy Marshall strawberry plant in the greenhouse. B. Leaf from Missionary variety in the greenhouse. Note the pin-point and streak chlorotic areas due to crinkle disease. C. Leaf from Corvallis variety in the field, November. Note pin-point chlorotic areas, abnormal dentation, and curled leaflets due to crinkle disease. D–F. Leaves from Marshall variety in the field, November. D and E produced in late fall and showing characteristic symptoms. F produced in late summer and showing little chlorosis but characteristic crinkling and abnormal margins.

In the greenhouse, selections of runner plants have been made through two generations. Both healthy plants and those affected with crinkle were selected, segregated, and planted in pots, and the runner plants from these have been planted singly into pots of sterile soil. In all cases where parent plants were healthy the runner plants have remained healthy, but in cases where the parents were "crinkled" every runner plant from them has shown symptoms of crinkle sooner or later. This behavior has become the basis for selecting runner plants or for roguing fields to eliminate the disease from planting stock.

It was hinted above that in fertile soils runner plants do not always show symptoms soon after rooting. When affected runner plants were potted into fertile soil in the greenhouse sometimes the leaves produced for a time subsequent to potting were without symptoms, but in a few weeks the symptoms returned on leaves produced later. Whether this temporary recovery is entirely due to fertility or to some other factors, such as self-induced toxicity of the soil, is a question.

This temporary recovery is noticeable in some soils in the field and has a very practical bearing on selection of planting stock in the late fall. In plantings less than a year old one can not be sure to recognize the disease, while in older plantings the parents and most of the runner plants exhibit disease symptoms. This indicates that where autumn roguing is necessary planting the previous fall is desirable.

An investigation of the cause of crinkle is now under way at the Oregon Agricultural Experiment Station. In August of this year affected plants were sent to the U. S. Department of Agriculture, Division of Nematology, for examination, but no parasitic nematodes were consistently found in the leaves, buds, or roots. The symptoms and behavior of the disorder suggest the probability of a virosis rather than a disease of fungous or bacterial origin. Whatever the cause, there are indications that the disease spreads in the greenhouse and in the field.

Perhaps the best evidence of the transmission of the disease is the fact that some of the new hybrids distributed from the U. S. Department of Agriculture have contracted the disease in Oregon. These hybrids originated at Glenn Dale, Maryland, where George M. Darrow, of the U. S. Department of Agriculture, believes crinkle does not occur. Some of this stock was planted near the Marshall variety affected with crinkle at the Oregon Agricultural Experiment Station, Corvallis. Now, some of this stock growing at Corvallis and some of it, which has been distributed to growers elsewhere in the State, have developed crinkle.

In the greenhouse crinkle has shown up in the U. S. D. A. 227-A and the Missionary, both of which were growing in pots near affected plants of the Marshall variety. Whether this transfer took place in the greenhouse

or in the field before potting is not known, but these two varieties are not grown commercially here, being introduced for experimental purposes from Eastern or Southern States. In commercial fields the disease seems much more prevalent than a few years ago, sometimes more than half of the plants being affected by the third year.

Experiments have been started by the junior writer to determine the possible insect vectors and whether crinkle may be transmitted by means of grafting healthy and diseased tissues or by the injection of juices extracted from diseased tissues.

Fortunately, practical measures based on our present knowledge of the crinkle disease can be instituted to materially better the planting stock of affected varieties. The practicability of selection and roguing to eliminate crinkle from the Marshall variety has been demonstrated and has led to the certification of strawberry plants in the State of Washington.[5] In the selection of plants and roguing for this certified stock the purpose was to eliminate all abnormal plants. Some of this stock, planted in several places in Oregon, shows almost complete elimination of crinkle.

Doubtless, where very high percentages of the disease exist, fields should be abandoned as sources of planting stock, but selection of normal plants could be advised in fields containing perhaps 10 to 20 per cent of crinkle, while roguing is practicable only in cases of less than about 5 per cent.

SUMMARY

In this paper is described for the first time a strawberry disease that, so far as known, is limited in distribution to the Pacific Coast States. Its symptoms and behavior in the field would suggest that it may be a virosis, although its transmission from diseased to healthy plants has not been proven experimentally. There is considerable circumstantial evidence that this disease, for which the name "strawberry crinkle" is proposed, is transmitted under field conditions. Practical methods of eliminating the disease from planting stock by means of roguing or selection are deemed successful.

[5] Hunter, E. D. State certification of strawberry plants. Better Fruit 24 (9): 31–32. 1930.

KEEPING QUALITY AS A FACTOR IN SELECTING NEW VARIETIES OF SMALL FRUITS

NEIL E. STEVENS

During the past 15 years much of my time has been given to the study of the rots of small fruits, especially those that develop after the fruit is picked. Most of the work directed toward the control of these rots has been done in active cooperation with the refrigeration and transportation projects of the Bureau of Plant Industry, with claims prevention officers of the transportation companies, and with sales companies and sales agents. This cooperation has been exceedlingly pleasant and profitable. There is, therefore, no danger of any misunderstanding of the statement that if I were to start another 15-year period on the same project I believe my cooperation would be chiefly with plant breeders.

I am conscious of the scientific and practical value of the information gained in the studies of refrigeration and transportation. Much progress has been made in the shipping and refrigeration of strawberries, for example, since that day in 1860 when C. S. Dod (1) shipped strawberries a distance of 474 miles by railroad in a refrigeration chest, in which berries were held in tin cups placed on a platform of wood resting on spiral mattress springs and on the top of the whole a box 4 in. deep holding ice, or even since 1868 when D. W. Davis (3, p. 444; 6, p. 574) of Detroit made an experimental shipment of strawberries from Cobden, Illinois, to Buffalo, New York, in a specially designed car. In this car, which was insulated, galvanized iron tanks to contain a mixture of ice and salt were arranged along the sides.

Strawberry growing in the South depends for its existence as a major industry on the possibility of delivering the fruit in salable condition to large northern markets, which means two things—a variety that will ship and adequate means of transportation. The same may be said of the other large fruit industries of the Southern States. W. A. Taylor (6) traces the successful development of the Georgia peach industry to the origination of a variety (the Elberta) better adapted to long shipments than any previously known and to the development of a car service adequate for fruit transportation.

The point I am trying to make is that of these two essentials, an adequate variety and proper transportation, too little attention has been given to the question of selecting a variety. In other words, this commercial structure we have erected, buttressed by careful handling, rapid transit, and refrigeration, rests on a rather weak foundation, for the fruit itself is of varieties that are of a poorer keeping quality than may well be obtained.

Moreover, whatever further improvements can be made in handling, refrigeration, and transportation may be even more advantageously applied to varieties of fruit having better carrying qualities than those now grown.

CHANGING CONDITIONS IN THE TRANSPORTATION OF PERISHABLE FRUIT

While it is, of course, possible that refrigeration equipment and methods may be greatly improved and perhaps radically modified in the future, it is evident that changing conditions in transportation of very perishable commodities in the eastern United States are rendering of relatively less value our present knowledge of refrigeration. The rapid increase in non-refrigeration truck transportation is hard to comprehend unless one is closely in touch with the development. A summary[1] of motor-truck movement, prepared by the United States Department of Agriculture in co-operation with the Delaware State Board of Agriculture, points out:

> "For strawberries, the shipments from the Eastern Shore section, (Maryland, Delaware and Virginia) by rail and boat in 1928 amounted to 2,131 carloads compared with a reported motor-truck movement equal to 2,396 carloads. It is interesting that records available indicate that, in 1926, the rail shipments of strawberries were 2,862 cars compared with 1,086 'carload equivalents' reported by motor-truck, thus showing a large increase in the use of the motor truck during the last two years."
>
> "Motor truck shipments from the Eastern Shore in 1928 went to points as far distant as Boston and Buffalo."

A somewhat similar survey (4) of the region around Greater New York indicates that in 1928 almost ¾ (72.9 per cent) of the fruit and vegetable production of New York and New Jersey that moved into New York City was carried by truck.

The movement of strawberries from North Carolina to northern markets by motor truck began in a small way in 1926 or 1927. No exact figures are available, but it is known that in 1927 only about 20 loads of strawberries were delivered to Philadelphia[2] from North Carolina; all the rest came by rail. So rapidly did trucking of these commodities increase, however, that in 1929, 1,483 carloads were sent by rail as against 397 "carload equivalent" by truck. In 1930 the ratio was 756 cars by rail—467 "carload equivalents" by truck.

[1] Edwards, Brice, and J. W. Park. Motor-truck movement of fruits and vegetables from Delaware and the eastern shores of Maryland and Virginia—1928. 25 pp. U. S. Dept. Agr., Bur. Agr. Econ., in cooperation with Del. State Bd. Agr., Washington, D. C. 1929. (Mimeographed).

[2] Lensen, W. G., and J. W. Coleman. The Philadelphia strawberry market. Season of 1927. Summary. 8 pp. U. S. Dept. Agr., Bur. Agr. Econ., Fruit and Veg. Div., Market News Serv. 1927. (Mimeographed).

A future development, which is entirely possible with such expensive products as Florida strawberries and which has already been tried out, if newspaper reports may be credited, is airplane transportation.

The latest aid to refrigeration, solid carbon dioxide, appears, according to Brooks (2), less promising as a means of controlling rots of strawberries in transportation than of such fruits as dewberries, grapes, plums, and cherries.

THE POSSIBILITY OF SECURING VARIETIES OF BETTER CARRYING QUALITY

It is not necessary for present purposes to argue as to whether truck transportation has come to stay, whether solid carbon dioxide can be economically used, or whether strawberries should be carried in airplanes; the point I am trying to make is that small-fruit transportation is undergoing changes and that one of the present needs is to give attention to the selection of varieties on the basis of keeping quality.

To assist in this work it is certainly not necessary for the pathologist to become a plant breeder. Our friends, the geneticists, will welcome cooperation, and they assure me that selection among the results of their crosses is much more difficult than the crossing and propagation itself. The very least that the pathologists ought to do is to discover for each variety of fruit what characteristics seem to result in or at least are to be associated with better keeping quality. Armed with this information the breeder can work much more efficiently.

One thing must be evident—this plan certainly does not mean sacrificing eating quality for keeping quality. In making selection on the basis of keeping quality we shall concern ourselves only with varieties that have already been carefully selected for their horticultural characters, size, color, and flavor. As an illustration of the range of variation in keeping quality among varieties already selected for further study because of excellent horticultural characteristics and eating quality, two examples may be cited—the blueberries bred by F. V. Coville and the strawberries bred by G. M. Darrow, both of the Bureau of Plant Industry. In fact, it was my incidental observations of the great range in keeping quality shown by the plants grown in their trial plantings that first aroused my interest in this subject.

The difference in keeping quality of blueberry varieties of proved horticultural value and high eating quality and the tests by which these differences are determined experimentally were described several years ago in this journal (5). This work has already entered into commercial practice among blueberry propagators. The results of a number of such tests made each year on promising new blueberry crosses are placed in the hands of the growers and are considered by them in deciding what varieties to propagate.

A somewhat similar difference in keeping quality appears among strawberry varieties. (See Table 1).

TABLE 1.—*Comparative keeping quality of fruit of 6 strawberry crosses and of the Missionary variety grown at Glenn Dale, Maryland, in 1929, as indicated by average percentage of sound berries at end of keeping test*

Variety	Number of tests	Average percentage sound after 2 days at 20° C.	Average percentage sound after 1 week at 7–10° C.
632	4	95	78
542	4	91	91
Missionary	6	80	66
682	4	65	49
520	4	63	49
25	5	43	30
652	5	38	12

This table shows the wide range in keeping quality of the various crosses from approximately 91 per cent to only 12 per cent sound after a week in cold storage. It also shows that under growing conditions obtaining at Glenn Dale, Maryland, in 1929, two of the crosses, both of excellent eating quality, showed a keeping quality superior to that of Missionary, a standard variety used as a check.

The importance of breeding to secure small fruits suitable for canning and for frozen packs is already recognized (7). The suggestion that we test our small fruit crosses and select with a view to securing fruit of better quality or even that in the case of raspberries or strawberries we breed purposely for keeping quality is merely proposing that we do quickly and purposefully what is apparently done slowly and expensively (and more or less unconsciously) by a process of natural selection. It is obvious to any but the most casual observer that keeping quality must have been a large factor in the commercial survival of such important varieties as the Elberta peach, Klondyke strawberry, and Howes cranberry.

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LITERATURE CITED

1. ANONYMOUS. Carrying strawberries to a distant market. Amer. Farmer V, 2: 301. 1861.

2. BROOKS, CHARLES. Effects of solid carbon-dioxide upon transportation diseases. Ice and Refrig. 81: 48–50. 1931.

3. EARLE, F. S. Development of the trucking interests. U. S. Dept. Agr. Yearbook **1900**: 437–452. 1901.
4. PRICE, B. M. The motor truck as a carrier of fruits and vegetables to greater New York. New Jersey Agr. Exp. Sta. Bul. 503. 1930.
5. STEVENS, N. E. A method of testing the keeping quality of certain small fruits. Phytopath. **19**: 593–596. 1929.
6. TAYLOR, W. A. The influence of refrigeration on the fruit industry. U. S. Dept. Agr. Yearbook **1900**: 561–580. 1901.
7. TUKEY, H. B. The trend in new fruit varieties. Proc. Ohio State Hort. Soc. **64**: 112–124. 1931.

BOOK REVIEW

Fischer, E., und E. Gäumann. *Biologie der pflanzenbewohnenden parasitischen Pilze.* 428 pp. Gustav Fischer, Jena. 1929.

Here at last is a book on principles of plant pathology and, better still, a good one. Several excellent books on plant diseases have appeared in the last few years, but most of them deal with the applied phases of plant pathology, with diseases arranged according to their causes or the crop plants they attack. Klebahn's "Grundzüge der allgemeinen Pflanzenpathologie" summarized some basic viewpoints but is now somewhat out of date and does not contain sufficient detail. It marked, however, a step in the right direction. But "Die Biologie der pflanzenbewohnenden Pilze" marks an epoch—the clear recognition that modern plant pathology is in part a pure science, not merely an applied one. The authors discuss basic principles and classify pathologic phenomena; they do not catalogue individual diseases. While they discuss only the pathogenic fungi and diseases caused by them, their book is one of the most notable contributions to the literature of plant pathology because it is a departure from the traditional viewpoint of diseases as a series of separate phenomena.

In a short introduction the authors discuss parasitism, saprophytism, and symbiosis. The main part of the book is divided into two parts: Part I deals with the prerequisites for the development of parasitic relations between pathogens and host plants, and Part II deals with the development of the parasitic relationships.

In Part I (The Prerequisites for the Parasitic Relation) is described quite fully what is known at present about natural susceptibility and resistance and changes in resistance caused by soil and meteorological factors, injuries, and the attack of other parasites. There is a brief discussion also of artificial immunization. This is followed by a section on the nature of resistance. The authors then consider the prerequisites on the part of the parasite for infection, including a good discussion of the natural differences in pathogenicity of parasitic fungi, variability in pathogenicity, and the influence of physiologic specialization. This is then followed by a description of the ways in which pathogens survive unfavorable conditions, the different kinds of inoculum, the methods of dissemination, and the factors affecting germination and growth.

In Part II (The Course of the Parasitic Relation) is given a summary of the various methods by which parasites cause infection, including the methods of entrance into host plants, the histological relationships between pathogens and hosts, the fate of the mycelia inside of the hosts, including effect of environmental factors on the development of diseases, and the

fructification of pathogens on their host plants. This is followed by a consideration of anatomical and physiological changes caused by pathogens.

The general sequence in the book is logical, although some pathologists might prefer to have the order reversed: to consider pathogens first and then the host plants. The principal topics might then be in the following order: the nature of pathogens, production of inoculum, dissemination, the phenomena of inoculation, incubation, infection, the environmental factors affecting the development of the diseases, and, finally, the effects of the disease on the host plants. There are, however, advantages and disadvantages in both arrangements, depending on personal preference.

The book is, of course, in German, but the style is clear and concise; there are numerous headings, which enable the reader easily to retain his orientation; copious literature citations are given at the end of each chapter; there are numerous tables and graphs; some good illustrations, although more could have been used to advantage; and the book, in general, is well made.

The most important fact is that the authors have organized between the covers of their book the most important facts concerned with the development of diseases caused by fungi. They have culled the literature, evaluated the contributions, and organized them into a logical system. This is so significant a contribution that criticism of the relatively few faults in presentation and interpretation, including a few minor inaccuracies, would seem mere fault-finding.—E. C. STAKMAN, University Farm, St. Paul, Minnesota, and C. R. ORTON, University of West Virginia, Morgantown, West Virginia.